Renewable and Sustainable Energy Reviews 28 (2013) 130–165

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A guideline for assessing of critical parameters on Earth architecture and Earth buildings as a sustainable architecture in various countries

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ARTICLE INFO

Article history:
Received 2 March 2013
Received in revised form
9 July 2013
Accepted 14 July 2013
Available online 15 August 2013

Keywords:
Earth architecture
Earth building
Sustainable architecture
Questionnaire
Vernacular architecture

ABSTRACT

For thousands of years, Earth itself has been the most tried and tested natural construction material that can also be used to construct modern sustainable buildings in combination with modern methods. For centuries, humanity has understood very little of the technical and material properties of natural resources, often creating buildings and structures with serious failures in durability, strength and corrosion resistance. Many engineering properties have been understood in the past, and now more fully in highly developed societies, but with this increased knowledge, many other factors seem to have been lost. There has been no modern attempt to connect Earth′s architecture and Earth′s buildings, and this topic creates the foundation of this study. This study considers seven parameters including the role of national codes and the International Council on Monuments and Sites (ICOMOS), triggers, drivers, obstacles and reasons in the development of the architecture of Earth and Earth′s buildings. Other parameters stem from online questionnaires conducted in six countries that evaluated the importance of architectural styles, construction methods, materials, structural and economic aspects, climate conditions, and new technologies like nanotechnology. The online questionnaires were completed based on various aspects of the existing research, literature review and discussion with several senior architects and researchers at ICOMOS. The questionnaires were conducted in between 14 August and 14 November 2012, and the responses came from ICOMOS members from USA, UK, Australia, Iran, India and Malaysia. Upon completion the 763 survey responses were compared, which approximated a confidence interval of 95% and a margin of error of $\pm 5\%$. The responses were investigated using regression analysis for producing related equations on parameters and their relationship in each country. An average of 71% of the respondents found a lack of national codes and guidelines in all countries. Thirty-four percent of the respondents voted for acceptable ICOMOS influence in a shift toward more Earth architecture development. Around 32% of the respondents feel that a single factor, an integrated process where responsibility is shared, could be responsible for driving the Earth architecture in all countries. The main environmental reasons cited for Earth architecture by an average of 58% of the respondents included protection of the environment, minimizing the ecological impact of buildings, and waste reduction. The main social cause noted for Earth buildings by 34% of respondents was a moral imperative of being sustainable. An average of 58% of respondents voted that the main obstacles for the Earth architecture were lack of awareness, perceived higher upfront costs, and lack of education. Therefore, the survey results indicate that appropriate parameter choices and proper decisions in the design and construction stage could lead to developing Earth architecture and Earth buildings. These assessments of various parameters presented in this survey could be applied for the development of Earth architecture and Earth buildings in six countries.

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http://dx.doi.org/10.1016/j.rser.2013.07.020

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1. Introduction

Sustainable architecture is an architecture based on localized requirements and building materials and reflecting local traditions. The behavior of sustainable architecture evolves over time to reflect the environmental, cultural, technological and historical contexts in which it exists. It has often been dismissed as crude and unrefined, but has proponents which highlight its importance in the current design. The Earth architecture is a type of sustainable architecture. For thoUSAnds of years, Earth has been the most tried and tested natural construction materials, which in combination with modern methods can be used to construct modern sustainable and eco-friendly buildings. From many years to now, Earth-building techniques have been growing in Iran, USA and all over Europe and Middle East. The reason for this increase is the interest in eco-friendly construction. At the same time, there is also an increase in new building products and technical developments in the production of sustainable building materials. The Earth is one of the most widely used construction materials for different architectural applications such as building, hills, shaped hills, Earth sheltered, terraces, garden, landscape sites. In most instances the use of Earth in the western developed countries is confined to Earth walls only; however, Earth walls can sometimes constitute quite a small percentage of the structure of a building. In many developing countries where the properties of Earth construction are more widely appreciated, Earth is utilized in the construction of floors and roofs in addition to walls. Buildings made with Earth are economical, energy-saving, eco-friendly and sustainable. Earth buildings include adobe, cob, straw and rammed Earth blocks and walls. Worldwide, traditional Earth-construction techniques are known by various names such as cob, rammed Earth, pise de terre, adobe, clay lump and mud. The Earth used in various construction techniques may be stabilized with cement, lime or bitumen. The type of stabilizer depends on the type of clay present in the Earth and the desired modification of built properties. Appropriate stabilizers normally tend to increase the strength and, therefore, improve the durability of the fine product. This is particularly important in areas that experience particular inclement wheatear and often allow the Earth construction to acquire a greater strength more quickly. In case of using inappropriate or incorrect stabilizers, however, the stabilisers can have negative effects upon the properties of an Earth building. All these methods have been used successfully according to the local conditions, customs and materials. In this study, the impact assessment of critical parameters on Earth architecture and Earth buildings as a sustainable architecture is investigated.

Unlike other living organisms that seek a balance with nature to ensure their survival, human beings are concerned with only the immediate satisfaction of their “needs”, which may in turn cause the exhaustion and the collapse of the ecosystem part of which they are an integral part. And this happens despite the fact that scientific communities have been alerting all of us on the drastic effects of our activities that have on the ecosystem [1–4]. The construction industry is one of the largest and most active sectors throughout Europe representing 28.1% and 7.5% of the employment in the construction industry and the European economy, respectively. With an annual turnover of 1200 billion Euros, this sector represents 25% of all European industrial productions, being the largest exporter with 52% market share. In the global scenario, the construction industry is growing at a fast pace. For instance China will need 40 billion square meter of combined residential and commercial floor spaces over the next

20 years, equivalent to adding one New York or the area of Switzerland every 2 years [5]. Environmentally speaking, this industry accounts for 30% of the carbon dioxide (CO_2) emissions and consumes more raw materials (about 3000 Mt/year, almost 50% by weight) than any other economic activity, which shows a clearly unsustainable industry. The foreseeable increase in world population (by 2030 it is expected to increase by more than 2000 million people) and an increase in building and infrastructure needs will further increase the consumption of nonrenewable materials as well as waste production. Therefore, the use of more sustainable construction materials and construction techniques represents a major contribution to the eco-efficiency of the construction industry and thus to a more sustainable development. In the last decade, almost one hundred research articles on this subject, mostly related to rammed Earth, have been published in *Scopus*. This is just a small fraction (less than 10%) of all the research articles published on Portland cement concrete in the same period (the largest-volume manufactured product on Earth [6] and responsible for 5% of the world's CO_2 emissions), but it represents a tenfold increase compared to the research articles concerning Earth construction published in the 1990s. This means that more and more research efforts are being dedicated to transform the current building industry into a more sustainable one. In this particular context, Earth construction assumes an environmental advantage that makes it extremely competitive when compared to conventional construction materials and construction techniques. The majority of investigations carried out in this field are mostly related to the seismic response of Earth buildings, mechanical properties of Earth masonry and, more recently, their thermal and hydrothermal performances. The authors found only one review paper about the selection of Earth [7]. The present study reviews the important aspects related to Earth construction. It addresses economic advantages, consumption of non-renewable resources, waste generation, energy consumption, CO_2 emissions, toxicity and indoor air quality. There is no consensus about the date when human beings began to use Earth construction. Minke [8] mentioned that this may have happened over 9000 years ago based on the fact that Earth blocks (adobe)-based dwellings were discovered in Turkmenistan dated from a period between 8000 and 6000 BC. Other authors [9] mentioned that the use of Earth for the construction purposes dates from the period of El-Obeid in Mesopotamia (5000–4000 BC). According to Berge [10], the oldest adobe blocks were discovered in the Tigris River basin dated back to 7500 BC, so Earth construction could have been used for more than 10,000 years. Although the exact time frame when Earth construction began is not clear, the theories still point that Earth construction began with the start of early agricultural societies, a period whose current knowledge dates from 12,000 to 7000 BC. There are countless evidences of Earth buildings that were built 1000 years ago and are used in the 21st century. Even the Great Wall of China, the construction of which began about 3000 years ago, has extensive sections built on rammed Earth. Evidence shows the use of Earth construction by the Phoenicians in the Mediterranean basin including Carthage in the 814 BC. The Horyuji Temple in Japan has rammed Earth walls built 1300 years ago [11]. The author refers to the existence of rammed Earth-based buildings in the Himalayan region built in the 12th century. Adobe-based buildings structures are common in Central America. The ruins of the city of Chanchán in Peru are among the most ancient Earth constructions [12]. Some other good examples of ancient Earth constructions are the village of Taos in New Mexico (1000–1500 AC) and the city of Shibam in Yemen with Earth buildings up to 11 floors that were built 100 years ago [13]. Currently almost 50% of the world's population lives in Earth-based dwellings [14]. The majority of Earth construction are located in less-developed countries, however, this kind of construction can also be found in Germany, France or even in UK that has an excess of 500,000 Earth-based dwellings. Earth construction has also increased substantially in US, Brazil and Australia largely due to the sustainable construction concept, in which the Earth construction plays a key role. The French laboratory CRATerre founded in 1979 and linked to the School of Architecture in Grenoble, which acquired an institutional dimension in 1986 through the recognition of the French Government, has been capable of maintaining a strong and steady action in the promotion of Earth constructions. Houben et al. [15] mention the success of an educational project undertaken in CRATerre, consisting of a scientific workshop with over 150 interactive experiences, that had been attended by 11,000 visitors in just 4 years. As for Germany, Schroeder et al. [16] report the existence of vocational training and courses on Earth constructions that confer the expert title in this area. Three universities that offer Earth construction courses are the University of Kassel, the University of Applied Sciences in Potsdam and the University of Weimar (Bauhaus). Earth construction depends not only on adequate training but also on specific regulations. Several countries already have Earth construction-related standards. In Germany, the first Earth Building Code dates back to 1944, but only in 1951 with DIN 18951, these regulations were put into practice. In 1998, the German Foundation for the Environment disclosed several technical recommendations known as the "Lehmbau Regeln" [17]. Over the years, these recommendations have been adopted by all German states except Hamburg and Lower-Sáxony. A revised version of the 'Lehmbau Regeln' was passed in 2008. Australia is one of the first countries to have specific regulations on Earth constructions. The Australian regulations called "Bulletin 5" were published in 1952 by the Commonwealth Scientific and Industrial Research Organization (CSIRO). This document was revised in 1976, 1981, 1987 and 1992. In 2002, this document was replaced by the Australian Earth Building Handbook [18]. In 1992, the Spanish Ministry of Transport and Public Works published a document entitled "Bases for design and construction with rammed Earth" to support not only rammed Earth but also adobe-based buildings. Recently Delgado and Guerrero [19] stated that Earth construction was not yet regulated, posing several drawbacks such as the need to contract a building insurance during the 10-year warranty period. Various researchers have done but none have conducted any successful evaluation on Earth buildings until now! Smith [40], Laman [39], Nguyen et al. [38], Rijal and Yoshida [37], Abdel Aziz and Shawket [36], Dili et al. [35], Al-Temeemi and Harris [34], Assefaa et al. [33], Deuble and Dear [32], Wong and Seow Jan [31], Al-Khaiat and Fattuhi [30], Kim et al. [29], Chan and Kumaraswamy [28], Akinsola et al. [27] and Grac et al. [26] conducted various researches to investigate the building factors in various buildings such as vernacular buildings, sustainable buildings and green buildings in different countries.

The main aim of this research is to predict the impact assessment of requirements of different countries by Earth architecture and Earth buildings as a type of sustainable architecture. Critical parameters included architectural styles, construction methods, materials, structural aspects, economic aspects, climate conditions, and new technologies in Earth buildings. Impact assessment of critical parameters included the evaluation of type of Earth buildings as sustainable buildings in Malaysia, Iran, USA, UK, Australia and India based on architectural styles, construction methods, materials, structural aspects, economic aspects, climate conditions, and new technologies such as nanotechnology in Earth buildings. Based on different aspects of existing researches, literature review and discussion with few senior architects and researchers, the questionnaire is completed. The questionnaire was to be completed by ICOMOS members and related organisations in six countries. The questionnaire was included based on critical parameters in Earth

buildings such as architectural styles, construction methods, materials, structural aspects, economic aspects, climate conditions, and new technologies in Earth buildings in six countries. It would be almost impossible to get responses from people who had never even considered 'Earth building and Earth architecture'.

2. Methodology

The assessment conducted for the effective parameters comprises of seven separate series as described below:

- First series: a study on the impact assessment of the effective parameters on earth buildings and earth architecture in Malaysia. The first part includes a review on earth buildings and earth architecture based on architectural styles, construction methods, materials, structural aspects, economic aspects, climate conditions, and new technologies such as nanotechnology in earth buildings in Malaysia. The second part analyzes the answers of Malaysian architects and engineers to the online survey about effective parameters and their influences on earth buildings and earth architecture in Malaysia.
- Second series: conducts the same trial, but focuses on Iran.
- Third series: conducts the same trial, but focuses on USA.
- Fourth series: conducts the same trial, but focuses on the United Kingdom.
- Fifth series: conducts the same trial, but focuses on Australia.
- Sixth series: conducts the same trial, but focuses on India.
- Seventh series: a comparison of the impact assessment of the effective parameters on earth buildings and earth architecture in these six countries. The first part includes a comparison on earth buildings and earth architecture based on the results of series 1–6 on their architectural styles, construction methods, materials, structural aspects, economic aspects, climate conditions, and new technologies such as nanotechnology in earth buildings. In this section, the prediction formulas of the impact assessment of the effective parameters on earth buildings and earth architecture are compared within these six countries.

It is thought that the research is meaningful to identify some factors as effective parameters influencing earth buildings and earth architecture in these six countries. It is anticipated that the findings from this study would allow possible information gaps in earth buildings to be identified, and to use the results in the lobby governments to direct funding into earth buildings and their architectural aspects, whilst identifying future avenues for research. The research also intends to assist the ICOMOS and the International Scientific Committee on Earthen Architectural Heritage (ISCEAH) and other non-governmental organizations to educate the building industry, creating more demand for earth buildings and earth architecture certification. Potentially this research could accelerate the construction methods and market, thus contributing to many advances in earth architecture and earth buildings. This research also intends to help ascertain how well expectations of earth buildings and their architectural aspects were being met by the ISCEAH, enabling them to develop their training and education procedures to better meet these expectations. This research aimed to propose solutions to the obstacles and barriers currently preventing the uptake of earth buildings, allowing the architects' and engineers' societies to aim for a much higher percentage of uptake, and have a more significant effect on the development of earth buildings and earth architecture. The additional benefits of earth buildings were seen to be promoting industry awareness, transforming the market, raising awareness and benefits of earth buildings, including non-financial benefits (e.g. productivity, health, and well-being), setting a standard for measurement of earth buildings, reduction of building impact on the environment, waste reduction/minimization, reduction of carbon dioxide, and reduction of resources use. While the above items are only some of the advantages, it emphasizes the need for an investigation in conjunction with good validation processes. Research of this nature can surely assist in the implementation of earth architecture and earth buildings in different countries.

2.1. *Design of questions and online survey based on effective parameters*

This study is quantitative in nature and utilizes a survey to fulfill the aim of evaluating the requirements of stakeholders and end-users, involving their understanding of earth building and earth architecture in these six countries. The questions were designed based on the literature reviews, interviews and discussions with various researchers, and a few questions were also established by the author. These questions are related to the International Scientific Committee on Earthen Architectural Heritage (ISCEAH): the International Scientific Committees, which are the vehicles through which ICOMOS and ISCEAH fulfill their goals by carrying out specialized studies and scientific inquiries in their respective fields on the various issues with which ICOMOS is concerned. For the purposes of ISCEAH, earthen architectural heritage is defined as the architectural, archaeological and cultural landscape heritage constructed of unfired clay/soil-based materials. This influence was also expected to strengthen with the impending release of earth buildings and earth architecture. The online survey was conducted through a questionnaire over the 4-week period from the 14 August 2012 to 14 November 2012. Longitudinal research lasting several months would perhaps have collected data from a greater number of responses and it would have increased the potential for bias, since new events motivate change and/or new information updates the knowledge base of the targeted population frame. As a result, this research was also seen to take a snapshot of the current status of earth building and earth architecture in six countries.

2.2. *Sample frame and target population*

The targeted population for the survey was Malaysia, Iran, USA, the United Kingdom, Australia and India, based on end-users and stakeholders of the earth building and earth architecture. For this reason, it was important to describe both stakeholder and end-user in the context of this study as the evaluation aimed to distinguish between these groups. Stakeholders were defined as ICOMOS members who have an interest and/or an involvement in the outcome of the earth buildings. As defined below, stakeholders include commercial property developers; investors, owners and property managers; residential developers and major portfolio owners; owner occupiers; major corporate tenants and retailers; building contractors; building product manufacturers and distributors; architects and draftspersons; engineers; property and construction professionals; research and non-government organizations; related interests (utilities, financial institutions, insurance companies, etc.). End-users, on the other hand, were defined as individuals who are directly included in the application of the earth buildings and in this context, someone who is desired to have accreditation. End-users involve assessors, consultants, and particular stakeholders (architects, designers, engineers).

2.3. *Sample selection*

The first step was the community with related ICOMOS societies and organizations assisting in the distribution of the online survey. An e-mail was sent to related organizations in these six countries with an introduction to the research and the

objectives of the study. Based on discussions with the relevant ICOMOS societies that agreed to the study, a link for online surveys was sent to the members via e-mail and members answered the questions in an online survey. Regarding the number of participating countries, it was determined based on the relevant organizations that sent their contacts from their databases. In total, four ICOMOS societies and two related organizations in other countries (Malaysia and India) agreed to support the online surveys.

2.4. Sample size

The sample size was determined using the Morgan method in each related ICOMOS society and organization. Table 1 shows the sample size. The non-mandatory technique used to determine the sample size meant collaborating with the cooperating organizations in these six countries. Based on this reliance of related institutes and organizations on whether or not to include their contact databases, an analysis was created from non-answers that increased the probability results that were not representative of the sample size. From the community of related ICOMOS societies and organizations, provided, the total number of sample sizes was 28 in Malaysia, 52 in Iran, 235 in USA, 175 in UK, 204 in Australia and 70 In India. Based on the identification of ICOMOS members that were associated with the building industry, the number of persons constituting these businesses was unknown, the size sample was assumed to be infinite; however, in order to achieve a confidence interval of 95% and a margin of error of $\pm$5%, the survey needed a sample of 763 responses to ensure an overall representative size sample.

2.5. Survey design limitations

2.5.1. Non-responses

A major concern is non-response and the associated bias in any survey analysis, particularly if the respondents differ significantly from the non-respondents. It is important to recognize that non-responses may severely harm the quality importance of an analysis and survey and, as a result, it needs a data prediction from the non-respondents [21]. It is likely that some form of non-response will occur, however, by using good design and survey techniques this can be substantially reduced and even prevented [21,22].

Two main types of non-response were identified as follows:

- Item non-response—where a part of an answer is missing from a unit data.
- Unit non-response—where no data are collected from a special unit.

In this research, unit non-response was more likely to happen and to potentially have a greater effect on the data than on item non-response.

2.5.1.1. Techniques to limit non-responses. To reduce the number of non-responses, the following techniques were used:

- *Revision of objectives*: in this instance the objective was to survey the earth buildings and earth architecture related professionals rather than the whole population of Malaysia, Iran, USA, UK, Australia and India. The topics included in the survey needed a separate level of information and hence the earth buildings and earth architecture, being of a more similar nature, produced similar answers.
- *Increasing knowledge*: in addition to assisting with the online survey, the related organizations from the six countries dedicated a portion of their respective newsletters to a paper outlining the study and the intended online survey, further informing their potential respondents and increasing the opportunity for a greater response.
- *Pre-notification*: an introduction e-mail was sent to related institutes and organizations in order to reduce the level of non-responses from each country.

Some methods used to prevent a low response rate were as follows:

- Provide clear knowledge, description of the aim of the online survey and applications of the results. Ensure that questions were clearly stated and all options were covered in the multiple choices.

2.5.1.2. Number of non-responses. The number of non-responses creates two problems for the analysis of any results. Firstly, it decreases the sample size, thus decreasing the accuracy of survey results that may be investigated. Secondly, it imports errors into the online survey and their results that are very important in analysis. The problem is that there is no way to know which non-responses affect the data, as Burkell points out. Burkell provides many methods to account for the non-responses. For example, if the results show a difference between subgroups, then the degree to which such differences are affected by non-responses can be predicted. This can be achieved using the analysis of variance (ANOVA) method (Burkell, 2006). Unless response rates are very high, these techniques effectively decrease the precision of the online survey data based on the offset made for the sample from non-responses; however, the ANOVA method can be conservative (Burkell). If the response rate is low, then the variance method can be overly conservative and can increase the probability for the underestimation of online survey results, although studies indicate that non-respondents outnumber the participants that answered questions on, both, expressed attitudes and demographics (Burkell, 2006). Based on this, the method for accounting for non-responses was to separate responses into two subgroups: those that responded before and those that responded after the reminder e-mail. In addition the *t*-test was used to evaluate the difference between these two groups.

Table 1
Morgan table for determining sample size.
Source: Krejcie et al. (1970).

N	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	246
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	351
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	181	1200	291	6000	361
45	40	180	118	400	196	1300	297	7000	364
50	44	190	123	420	201	1400	302	8000	367
55	48	200	127	440	205	1500	306	9000	368
60	52	210	132	460	210	1600	310	10000	373
65	56	220	136	480	214	1700	313	15000	375
70	59	230	140	500	217	1800	317	20000	377
75	63	240	144	550	225	1900	320	30000	379
80	66	250	148	600	234	2000	322	40000	380
85	70	260	152	650	242	2200	327	50000	381
90	73	270	155	700	248	2400	331	75000	382
95	76	270	159	750	256	2600	335	100000	384

Note: "*N*" is the population size. "*S*" is the sample size.

2.5.2. *Other sources of non-responses*

The research can include several problems based on the survey and participants. The problems themselves include several items, such as no clear means to number additional responses, ignored systems in the participants' e-mails, invalid e-mail addresses, anonymous e-mail addresses, persons who do not have Internet access during the survey period time. An important problem is using the related institutes and organizations, for example architects societies, etc., to participate in the study, since it is unknown to what level these organizations could affect the data, although the results are only a representative of the sample size rather than the entire society of building architects, etc., in the earth building and building industry.

2.6. *Questionnaire design*

The questions evaluated end-users and stakeholders' knowledge of earth buildings and earth architecture as sustainable buildings based on different parameters and factors. In the first part, it was anticipated that only ICOMOS members would cooperate, but in the second part, all related parties cooperated, although the main idea was that all sectors of earth buildings and earth architecture (as a sustainable building) were analyzed. The current research also provided a chance for separate analyses of those directly associated with the earth buildings, such as ICOMOS members, and those not associated with the earth buildings, such as most architects and civil engineers in the six surveyed countries. Most of the current research methodology was designed based on the methodology of related works in green buildings, such as the Australian and the United States green building reports, the Building and Construction Interchange 2006 and McGraw-Hill Construction 2005. However, the two later reports did not allow for error analysis created by non-responses. It should also be noted that there is no research about earth building analysis dating prior to December 2010, therefore, it was important in this research to start an online survey based on various factors in ICOMOS and related organizations in earth buildings and earth architecture in the six surveyed countries.

2.6.1. *Section classification*

The first part of the online survey was structured questions, which were based on the most important factors. The online survey considered the assumption that surveyors might withdraw and not complete the questions. The online website utilized a special instrument that collected all the answers until the participant either finally completed the survey or decided to withdraw; however, many online surveys only recorded an answer once the online survey was finished.

The online survey was created based on eight key parts as follows.

2.6.1.1. Industry and personal information (optional). Part I collected information from the participants about the professional role of the building industry and basic information related to their role in the industry. This part allowed the results to be separated into various parts, such as personal information, level of education, industry sectors, capability and a discussion on these various items ensues.

2.6.1.2. Background. The significance of these questions provided knowledge of earth buildings and earth architecture by various groups that are related to the building industry.

2.6.1.3. Earth building tools in construction. Part III focused specifically on earth building tools in construction and evaluated the knowledge and experience of participants with earth building tools.

2.6.1.4. National guidance and handbooks. Part IV was created specifically to evaluate the national committees in the six participating countries. Questions were asked on how a respondent predicted that they would use the national guidance (e.g. as a design guideline or to receive design, construction or training certification), the importance of national guidance in each country, the importance for Malaysia, Iran, USA, UK, Australia and India to achieve certification for their buildings, and the probability that the participants would further develop earth buildings and their architectural aspects, once they were available.

2.6.1.5. International Council on Monuments and Sites (ICOMOS/ISCEAH). This part is similar to part IV but evaluates the impact of ICOMOS on factors such as understanding how they are involved in the production of sustainable buildings, earth buildings, vernacular buildings and the building industry in Malaysia, Iran, USA, UK, Australia and India.

2.6.1.6. Triggers, incentives, obstacles, barriers and reasons for earth buildings and earth architecture. Part VI attempts to develop an understanding of what the respondents understood to be the triggers, incentives, barriers, obstacles and reasons for earth building and earth architecture. Various questions were developed by the researchers and architects who have worked for many years on earth buildings and their architectural aspects in Australia and the United States. The aim here was to develop an understanding of why the earth buildings and earth architecture were created, what drove so few countries to do this, and which barriers prevented other countries from following suit.

2.6.1.7. Technical information. Part VII included the information of earth buildings and earth architecture based on architectural styles, materials, structures, climate and applications in each country. The current part evaluates various aspects on earth buildings in these six countries based on the results.

2.6.1.8. Information requirements. The final part includes further questions aimed at collecting and providing a review of the requirements of the building industry, relevant to earth building and earth architecture, and to create better and more knowledgeable options about earth building and earth architecture.

2.6.2. *Survey questions*

Although the online survey aimed to collect the requirements of end-users and stakeholders, it was very important that the level of knowledge of earth architecture, earth buildings and sustainable buildings further was developed. Based on the above information, questions were separated into two main parts, outlined below:

- Knowledge questions—providing a background to the level of knowledge and information on earth buildings, earth architecture, sustainability, and also the drivers that develop earth buildings into industry buildings.
- Special questions—seeking responses regarding the implementation of the earth buildings, such as output type, training, accreditation.

2.6.3. *Question type and development*

The question design was very important, since a reliable outcome of results that avoid biases is necessary. A few questions were designed using a scale format, which was expanded to 7 points as opposed to a 5 point scale to accommodate for a large

variation between answers and evaluations. Other types of questions included “tick all which apply” categories and single answer “yes” or ‘no”. If information included from a question type proved less ‘rich’, then responses were predetermined as not allowing for sufficient variation in participants’ responses. Based on this method, the data were easily analyzed, however, different problems, such as difficulty and speed, needed to be analyzed via open ended questions, their advancement to be included was limited in this special research to one special question: ‘What do you see as the purpose of earth building tools’? The question does not aim to direct the respondents to a predetermined response, but rather to determine the respondent’s own ideas about earth building tools. The research further aims to determine current education on earth building tools in construction. The other question types were derived from the ‘additional comments’ on various issues. The questions were structured such that a comparison between various items can be done.

3. Online survey in Malaysia, Iran, USA, UK, Australia and India using architects and engineers in ICOMOS

3.1. Survey instrument

The main aim of this study was to evaluate the level and problems encountered by professional persons as end-users and stakeholders and their knowledge of earth architecture, the construction methods, the requirement of materials, and to analyze any potential barriers. According to the literature reviews, it was predicted that earth building and earth architecture would require some surveying forms before it was officially implemented in these six countries. This analysis is reflective of the organizations in the six surveyed countries and may help to increase earth buildings and earth architecture in these mentioned countries, although it can be used in different countries. Stakeholders are the specific persons who need more incentives and advantages regarding the function, aims and procedure of earth buildings and their architectural styles.

3.2. Web-survey interface

The survey was selected as a methodology and technique to evaluate the objectives and aim of this study. The survey analysis includes several advantages listed below (Gillham):

- Respondent anonymity.
- Lack of interviewer.
- Efficiency in collecting information from a large number of respondents.
- Possibility for very large samples.
- Flexibility of information, a wide range of data can be collected and can be used to study attitudes, values, beliefs, and past behaviors.
- Application ease.

An online survey is a good approach since all ICOMOS members and people in the building industry have an e-mail address. For this research, a specific e-mail was used that was sent to ICOMOS members and related organizations and their members in each country. It was seen to be the most effective and efficient technique to communicate with the building industry (architects, engineers, etc.) with the limited equipment and time available. It was an assumption of the research study that most persons in the building industry had an e-mail address and a connection to the Internet. Other survey options, such as face to face or discussion using the telephone, were deemed not suitable because the research extends to different countries. Using an online website and collection of the responses into a good format is a good solution. It can decrease the cost and errors, and has the advantage of speed. The online website can help to provide a clear layout for the investigator and a logical schematic that can assist to check results and aid understanding. It can assist to control the error influenced by non-responses. A main benefit of the online website was the capability for multiple responses at the same time. An online website has the potential problem that a participant may respond to the survey more than once, however, the website used for this survey implemented a computer IP address check for each survey. The online website that was used for the survey also considered the following factors:

- Time and length of time to complete the survey for each participant.
- Computer IP addresses to prevent completing multiple surveys by each participant.
- The capability to support a mass of responses by different participants in different countries.
- The capability to show results based on different items and factors.
- The capability to analyze data or export to SPSS or Excel.

3.3. Data analysis based on online survey results in each country

After finishing the online survey, the results were saved to SPSS and Excel formats and then the results were imported to Excel for the analysis of the results. The sets of data were organized according to their questions. The data were also separated into participants associated with related organizations and participants not associated with related organizations analyzed based on country. The results were also organized into ICOMOS members and related members with ICOMOS. These two groups were determined based on participants’ responses and the data were analyzed based on the time of the survey period.

3.4. Summary of method

The online survey was based on quantitative information to analyze the understanding of earth buildings, earth architecture and their contribution to sustainable buildings. The online survey was done through an online questionnaire over a 4-month period from 15 August 2012 to 14 November 2012. The total number of participants contacted was 763. The online survey comprises of 52 questions that evaluated the seven parts in the current research as the following:

1. Industry and personal information.
2. Background
3. Earth building tools in construction.
4. National guidance and handbooks.
5. International Council on Monuments and Sites (ICOMOS)
6. Triggers, incentives, obstacles, barriers and reasons for earth buildings and earth architecture.
7. Technical information.
8. Information requirements.

The data were imported to Excel and SPSS for a basic and more thorough regression analysis.

3.5. Analyze the relationship of effective parameters with earth buildings and earth architecture based on the online survey results

The questionnaire was designed to ask about effective parameters of earth buildings and earth architecture. The current section tends to identify correlations between the overall effective parameters on earth buildings and earth architecture based on the results of the online survey. Responses to these questions were inputted into the multiple regression analysis, which takes responses of the questionnaire then shows the impacts of these effective parameters on the prediction of the level and the development of earth building and earth architecture. The research used regression analysis from EXCEL.

3.6. Regression analysis method

Regression analysis is a technique for finding a relationship between a dependent variable and one or more independent variables: this relationship is called a regression function [23]. The regression analysis determines the impact of each of these independent variables on the prediction of the dependent variable. The regression analysis has two types:

- *Simple regression*: simple regression analysis finds a relationship between one dependent variable and one independent variable. The simple regression model is the following:

$$Y=\beta_0+\beta_1 X$$

where Y is the dependent variable (predicted by the regression model), X is the independent variable, β_1 is the coefficient of X and β_0 is the intercept (or constant).

- *Multiple regression*: multiple regression analysis finds the relationship between one dependent variable and several independent variables. The multiple regression models are the following:

$$Y=\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_k=\beta_0+\sum_{i=1}^{i=k}\beta_i X_i$$

where Y is the dependent variable (predicted by regression model), k is the number of independent variables, $X_i(i=1,2,\ldots k)$ is the ith independent variable from a total set of k variables, $\beta_i(i=1,2,\ldots k)$ is the ith coefficient corresponding to X_i, β_0 is the intercept (or constant), $i=1,2,\ldots,k$ and independent variables' index.

1. *Setup hypotheses*:
   - H_0 (null hypothesis): $\beta_i=0$.
     Independent variable, X_i, is not important in the prediction of the dependent variable (Y).
   - H_1 (alternative hypothesis): $\beta_i\neq 0$.
     Independent variable, X_i, is important in the prediction of the dependent variable (Y).

   If we have k independent variables, then we also have k null hypotheses and k alternative hypotheses; in other words, we test the significance of every independent variable (X_i) on the dependent variable (Y).
2. *Setup confidence level*: the confidence level is usually 95% so the level of significance is 0.05. Null hypothesis is rejected or proved using this level of significance.
3. *Analysis of these hypotheses*: according to the above description, the independent variables are responses to the effective parameters and the dependent variable is the response to the overall earth building in the online questionnaire. These variables were given to EXCEL then a multiple regression analysis was done resulting in EXCEL calculating one coefficient ($\beta_i(i=0,1,\ldots,k)$) and one P-value for each of the independent variables. The null hypothesis is rejected or proven using the P-value. If the P-value of X_i is less than the level of significance (0.05) then the null hypothesis is rejected, but if the P-value of X_i is greater than the level of significance (0.05) then the null hypothesis is proved.

4. Results

In this part, the results of the online survey are illustrated and discussed. This part elaborates on the effective factors of earth architecture, in addition to exploring further use and development of earth architecture and earth buildings in the six surveyed countries. This study includes two comparative analyzes involving seven effective factors based on expert responses. The details of the comparative analyzes are the following:

a. A comparative analysis of expert members' opinions about the acceptance of requirements of earth architecture and earth buildings is given in the following:

   1. Background.
   2. Earth building tools in construction.
   3. National guidelines and handbooks.
   4. The role of ICOMOS.
   5. Triggers, incentives, obstacles, barriers and reasons.

b. A comparative analysis of expert members' opinions about the technical requirements of earth architecture and earth buildings in the six surveyed countries is given in the following:

   1. Technical information.
   2. Information requirements.

   Furthermore, a **s**tatistical test is used in the comparative analysis of expert members' opinions about the acceptance of technical requirements of earth architecture and earth buildings. The test determines the degree of their importance and agreement, with a mean average (X), which comes from opinions of each country of respondents about technical features. A percentage scale is used to categorize the features. These five categories are the following:

   0–20% = lowest degree.
   20–40% = low degree.
   40–60% = moderate degree.
   60–80% = high degree.
   80–100% = highest degree.

   The t-test is used to find out whether experts' opinions from different countries are significantly different. The results of the tests are shown in this part.

c. A summary of respondents' opinions is formed about earth architecture and earth buildings based on the statistical analysis of technical requirements as a new guideline for the development of earth architecture and earth buildings.

4.1. Total response

The online survey received a total of 763 responses from the 12 building sector categories in the six surveyed countries as illustrated in Table 2. Population sizes used are based on direct discussion with national ICOMOS offices in each country.

The calculated sample sizes are based on the population sizes as illustrated in Table 2.

4.2. Response rate

The objective was to receive a return of at least 763 responses from the estimated 1480 ICOMOS members contacted, in order to achieve a confidence interval of 95% and an error margin of $\pm 5\%$. Once a total of 763 responses were received, the online survey was discontinued. The total number of participants was 1480 and based on the below equation, the response rate is 51%. The response rate relies on the volunteer method and the participants were selected from the International Council on Monuments and Sites (ICOMOS). The current research needs only 763 responses and not the entire 1480 participants in this survey.

4.3. Non-response problem

Non-response items were considered as a negative influence on the survey results. Thus all non-response items were removed from the data analysis.

4.4. Online survey results

4.4.1. Section 1

4.4.1.1. Background. Evaluation of the background was undertaken according to the interest and involvement in earth architecture, sustainability, earth building tools used in construction and earth materials. This part portrays the significance given to earth architecture and earth buildings as deemed by experts, which is a relevant reflection of the status and importance of earth building and earth architecture in their relative countries.

4.4.1.2. Interest level. To determine the level of interest in earth architecture and earth buildings by the architecture society, the survey asked: To what extent would you describe your level of interest?

Most ICOMOS experts showed a high level of interest in sustainability, earth architecture and earth buildings, earth building construction tools and earth materials. The results show a very high interest level (74%) in sustainability, earth architecture and earth buildings, earth building construction tools and earth materials. Figs. 1–6 show the overall participant interest in sustainability, earth architecture and earth buildings, earth building construction tools and earth materials in the six surveyed countries. Iranian and British experts are more interested in “earth architecture and earth building”, while Australian, Malaysian and American experts’ interests tend toward sustainability. Indian experts solitarily showed a main interest in “earth building construction tools”.

The results indicate that the interest level was greatly influenced by the historical background of earth buildings in each country. For instance, British and Iranian experts indicated a high interest in “earth architecture and earth buildings” because their countries included historical civilizations in earth architecture and earth buildings, while American, Australian and Malaysian experts selected “sustainability” because these countries are pioneer countries in sustainability. Indian experts expressed a high interest in “earth building construction tools” since this is the most relevant factor to their country in current times.

4.4.1.3. Involvement level. The next question tried to determine the degrees of involvement with the various factors. Participants were asked: What best describes your level of involvement with the various factors?

The involvement level is quite different than the interest level. Figs. 7–12 reflect participants’ involvement in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials. These results show that most members in Australia, UK, USA, and Malaysia are involved with “sustainability”, but that most Iranian experts are involved with “earth architecture and earth buildings”, while most Indian experts are involved with “earth building tools in construction”. The results indicate that “earth buildings and earth architecture” need more attention and work in practice by related organizations and societies.

This section examined the degree of interest and involvement in “earth architecture and earth buildings”, “sustainability”, “earth building construction tools”, and “earth materials” by experts in the six surveyed countries. A disparity was recognized between interest level and involvement level in the earth building and earth architecture industry, suggesting that more attention needs

Table 2
Total population size of experts in the building industry and respondent sample size in the six surveyed countries.

Countries	Population size	Sample size
Australia	435	204
India	85	70
Iran	60	52
Malaysia	30	28
UK	320	175
USA	600	234

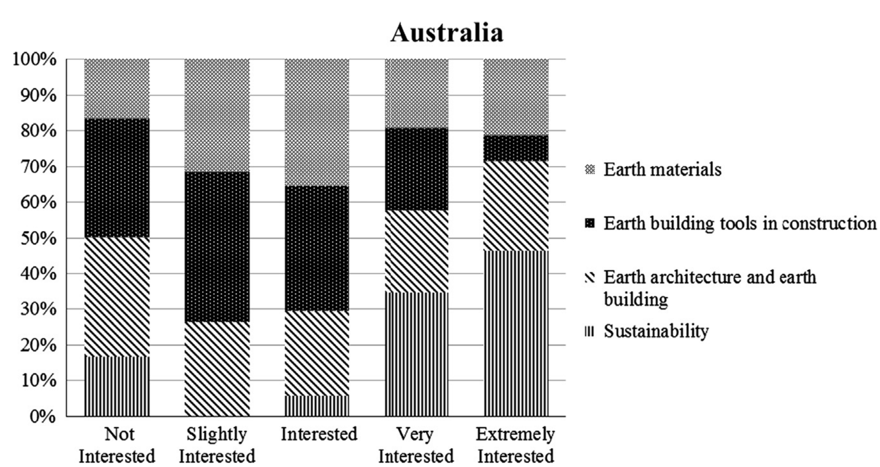

Fig. 1. Overall participant interest in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in Australia.

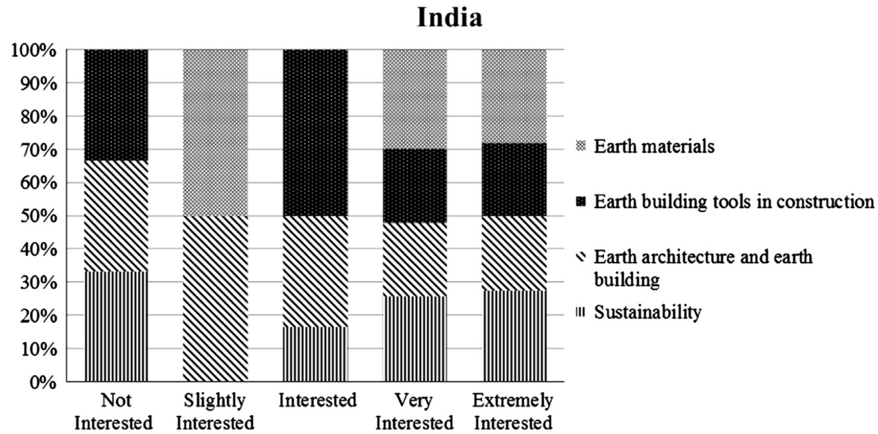

Fig. 2. Overall participant interest in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in India.

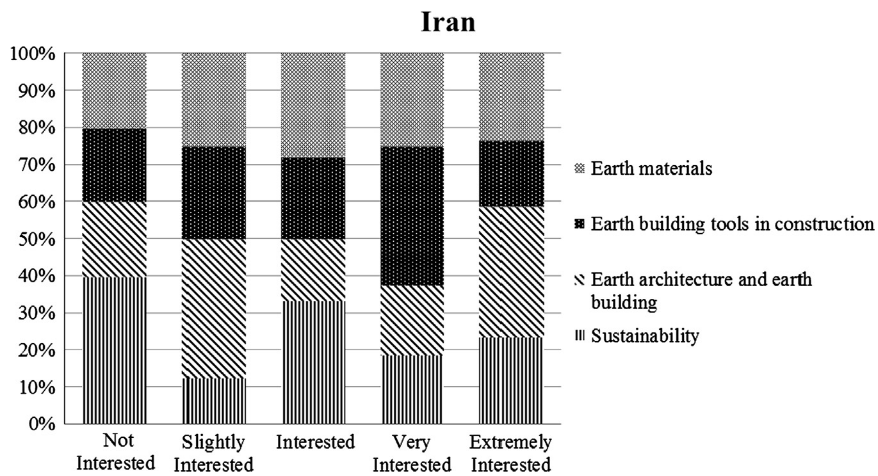

Fig. 3. Overall participant interest in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in Iran.

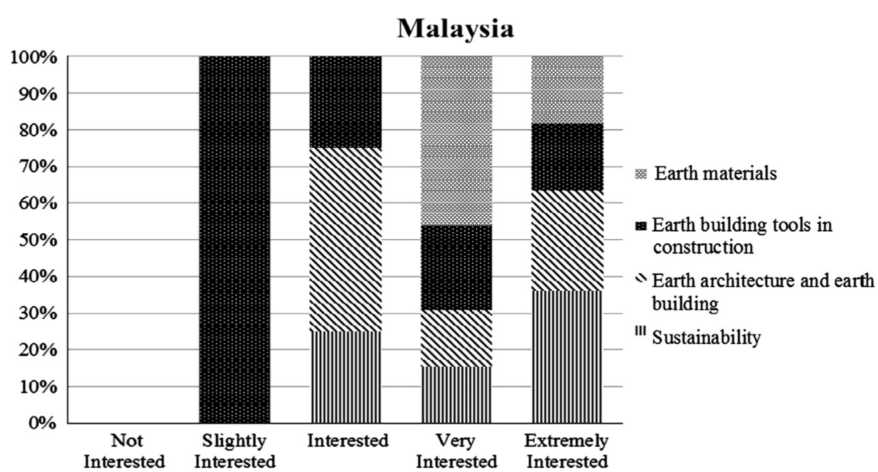

Fig. 4. Overall participant interest in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in Malaysia.

to be focused on earth architecture and earth buildings such as training courses, lectures, manuals for researchers, architects and engineers. Furthermore the results showed a greater interest level in “earth architecture and earth buildings” in Iran and UK, while “sustainability” was selected as the main interest in UK, USA and Malaysia, reflecting the perceived importance of the historical and cultural background of earth architecture and earth buildings in various countries. The results further indicate a weak involvement in earth architecture and earth buildings, suggesting that more attention and work by related organizations and societies is needed. The results indicate that the interest in “earth building construction tools” is generally very low, suggesting that more effort is needed in exploring “earth building construction tools” as a new parameter in the development of earth architecture.

4.4.2. Section 2

4.4.2.1. Earth building tools in construction. This section evaluates participants’ responses to “earth building construction tools” and explores their possibilities as new tools in earth architecture and

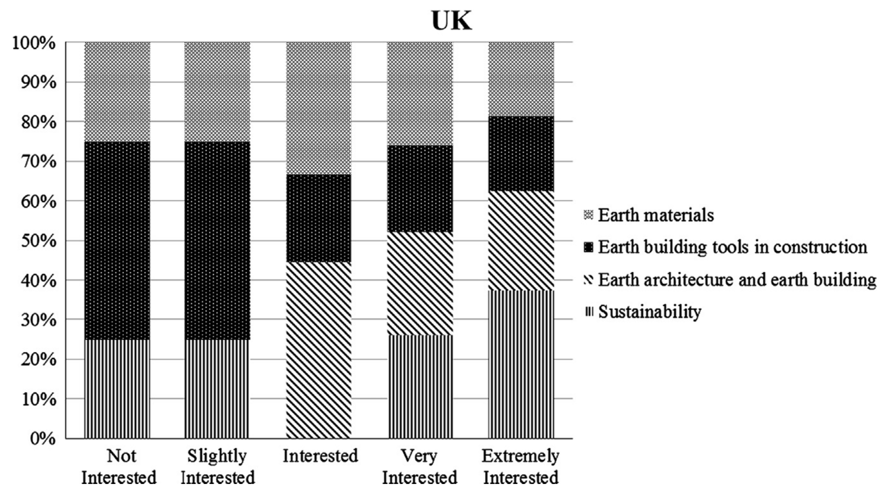

Fig. 5. Overall participant interest in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in UK.

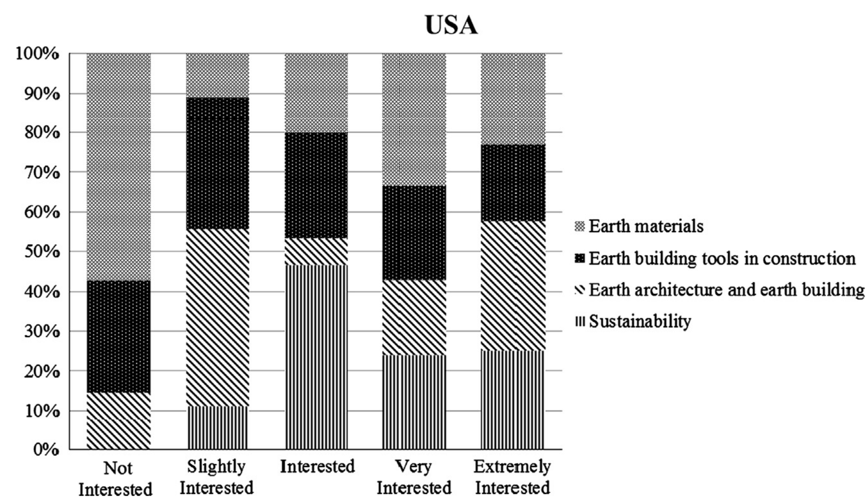

Fig. 6. Overall participant interest in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in USA.

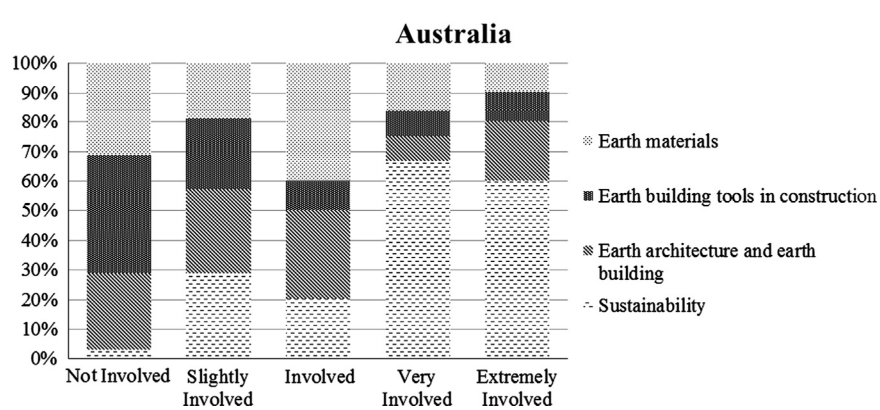

Fig. 7. Participant involvement in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in Australia.

earth buildings. The author suggests learning about these tools as a new discipline in earth architecture and earth building, considering the importance of earth architecture in the building industry.

4.4.2.2. Purpose of earth building tools in construction. The field specialists were asked: What do you see as the purpose of earth building tools in construction? The reason for this question was to evaluate participants' interpretation of what is the purpose of "earth building tools in construction", rather than what it is or does. Most responses were related to "sustainability" with 39% and "guideline development for design and construction" with 20%, as illustrated in Fig. 13. "Earth building construction tools" can be used as an effective factor in making decisions and undertaking development in earth architecture and earth building. This can be used as a tool to assist in the selection of optimized materials, technologies and methods in design and construction of earth

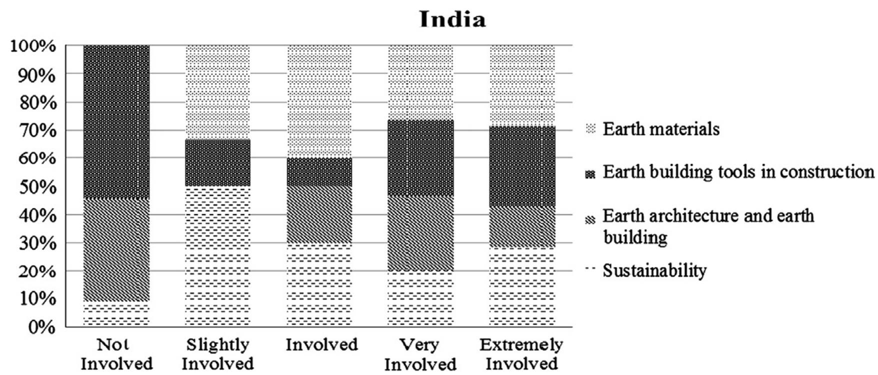

Fig. 8. Participant involvement in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in India.

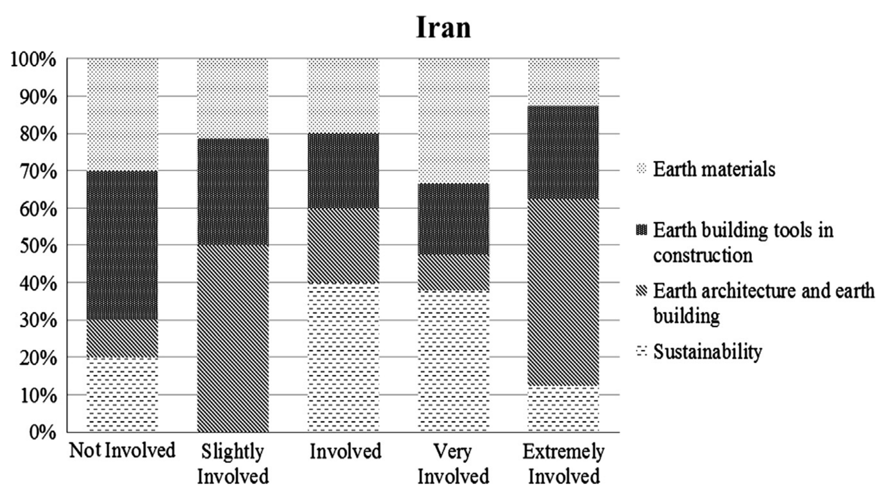

Fig. 9. Participant involvement in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in Iran.

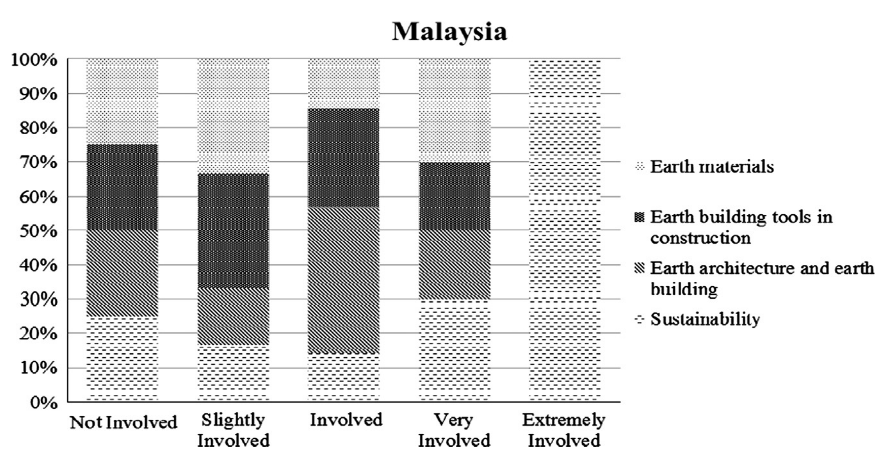

Fig. 10. Participant involvement in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in Malaysia.

buildings. Based on the results, "Earth building tools in construction" can develop good guidelines on earth buildings that can help in their sustainability and assist in cost effective earth architecture and its future in the world.

4.4.2.3. National codes rating tool. Respondents were asked: How important is it to have a national code covering earth building in your country? Based on the responses, having a national code in Australia, India, Iran, Malaysia, UK and USA was important, with 42%, 35%, 18%, 29%, 22% and 28% of participants rating it as "extremely important", 35%, 47%, 63%, 43%, 15% and 25% as "very important", and 17%, 5%, 5%, 12%, 35% and 14% as "important", respectively, as illustrated in Fig. 14. Only 6%, 22% and 18% of Iranian, UK and USA participants, respectively, selected "not important" in their responses. Experts deem national codes in each country as highly important because they believe national codes will increase the quality and quantity of earth buildings in their country. National guidelines can help architects and engineers in design and construction of earth buildings and earth architecture and, in practice, this can increase earth building projects in various countries.

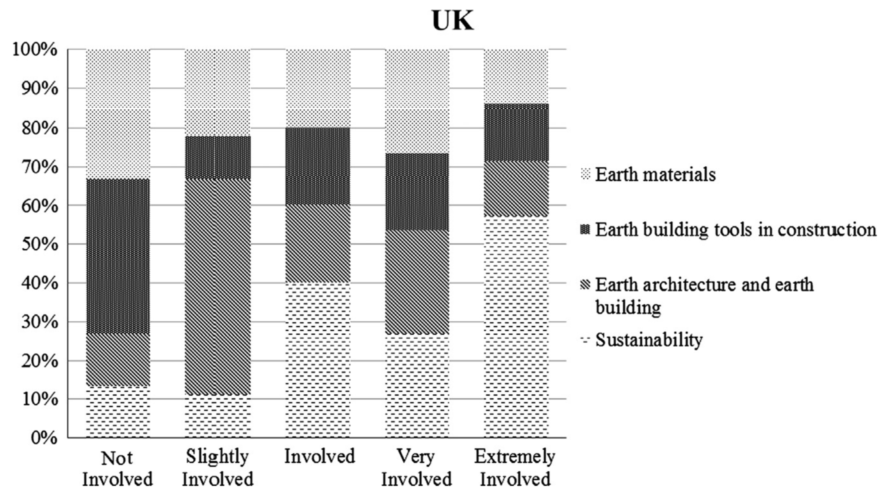

Fig. 11. Participant involvement in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in UK.

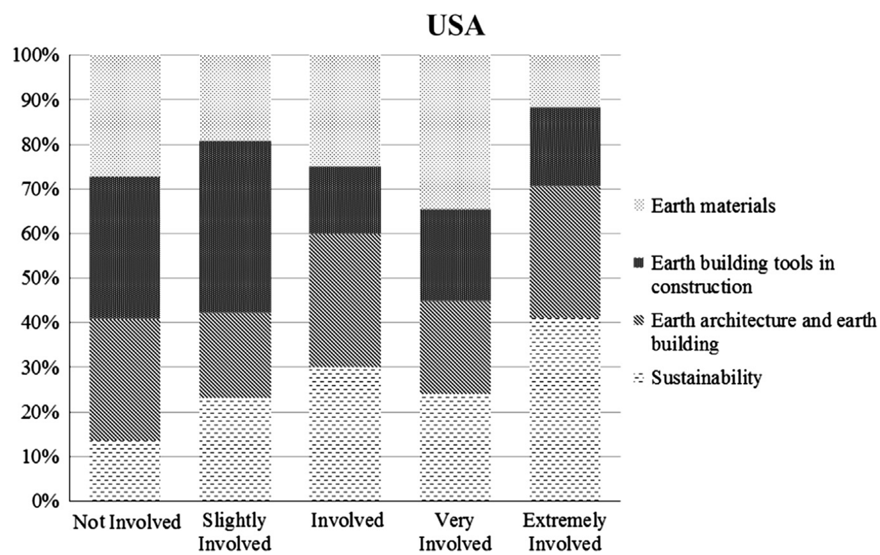

Fig. 12. Participant involvement in earth architecture and earth buildings, sustainability, earth building construction tools and earth materials in USA.

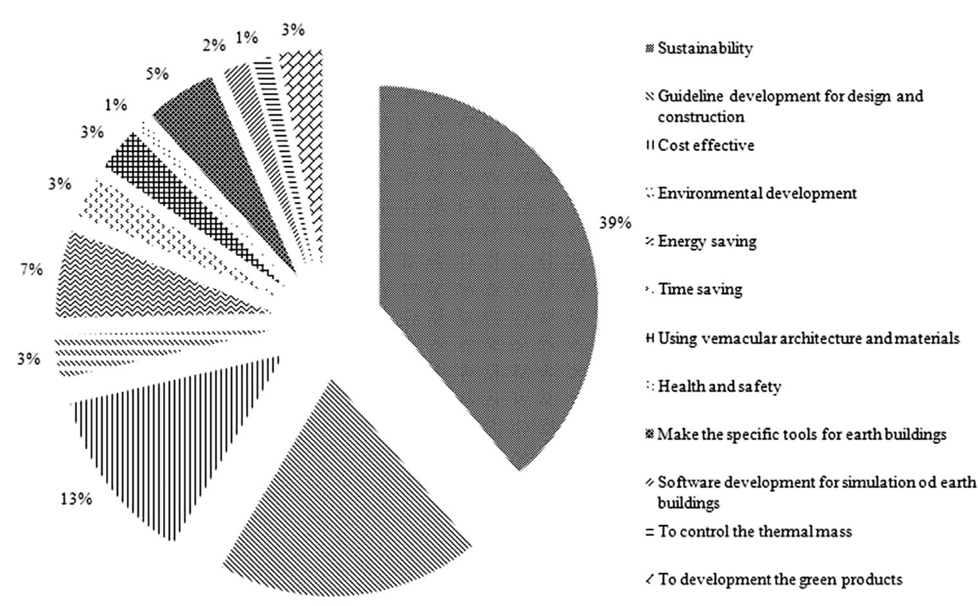

Fig. 13. Purposes of earth building tools in construction and their perceived significance as deemed by specialists in the field.

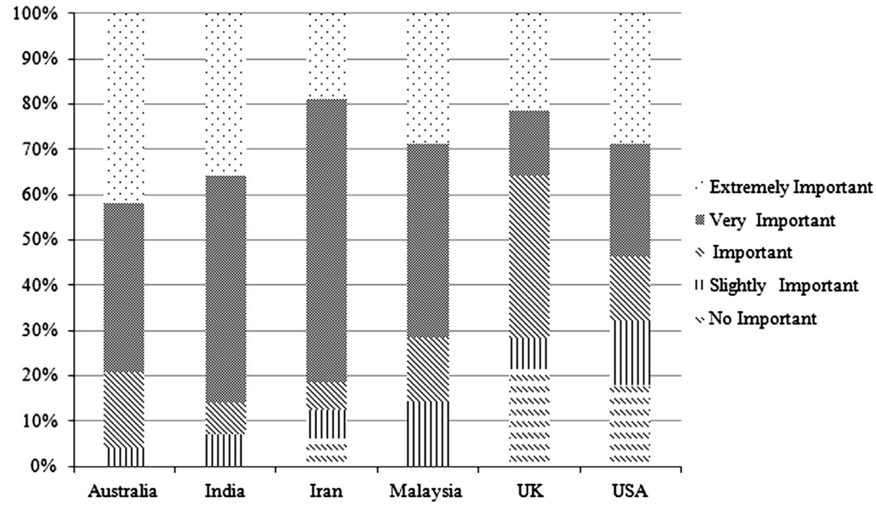

Fig. 14. Overall importance deemed to national codes by experts in the six surveyed countries.

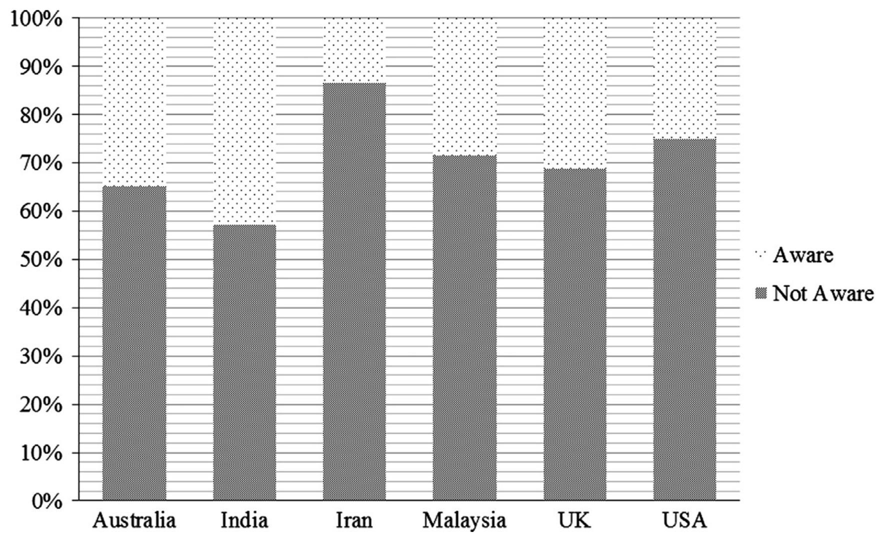

Fig. 15. Overall awareness of the current existing national codes by surveyed experts in their own countries.

4.4.2.4. Awareness of existing national codes for earth buildings. Participants were further asked: Of the current existing national codes on earth building, which are you aware of? Based on the results, most participants were not aware about the existence of national codes, but some participants were aware of other codes, such as the Germany code, Australian Earth Building Handbook HB195 2002 Standards, Chile, Peru, Brazil, NZS4297, NZS4298 and NZS4299, Peruvian Adobe Code, The Earth Building Codes in Australia, New Zealand, the UK, Germany, and the US Southwest, Indian code of standard materials and construction, CTE and European codes, New Mexico, as illustrated in Fig. 15. As expected, respondents were most aware of the German code. The Peru code recorded an awareness level of 36%, and NZS codes of 15%. The results show a lack of awareness in national codes in various countries because most experts were not aware of any national codes in their own countries.

4.4.2.5. Experience with the existing national codes. Respondents were asked: Of the current existing national codes on earth building, which do you have experience with (commercial or residential)? Which do you have a very good understanding of how earth building works, either through an application or through an involvement in the development process of creating the tool? Experience with national codes was considerably lower than its awareness. Results show that over 75% of participants have had no experience with any existing national codes in earth buildings, as illustrated in Fig. 16. While not as substantial as the awareness level, the German Code recorded the highest level of experience from respondents with 14%. The mean average of responses show that experts consider having experience with national codes better than its absence and that it needs more activities by governments, societies and related ministries in mentioned countries.

Experts were asked: In your experience with existing national codes covering earth building, what have been the highest achieved ratings/scores? Seventy percent of all respondents said assigning a highest achieved rating of national codes was not applicable as illustrated in Fig. 17. Based on the results, administrators in the building industry must revise their opinions on the existing national codes covering earth buildings, because experts believe that existing national codes are not suitable or applicable for the design and construction of earth buildings and earth

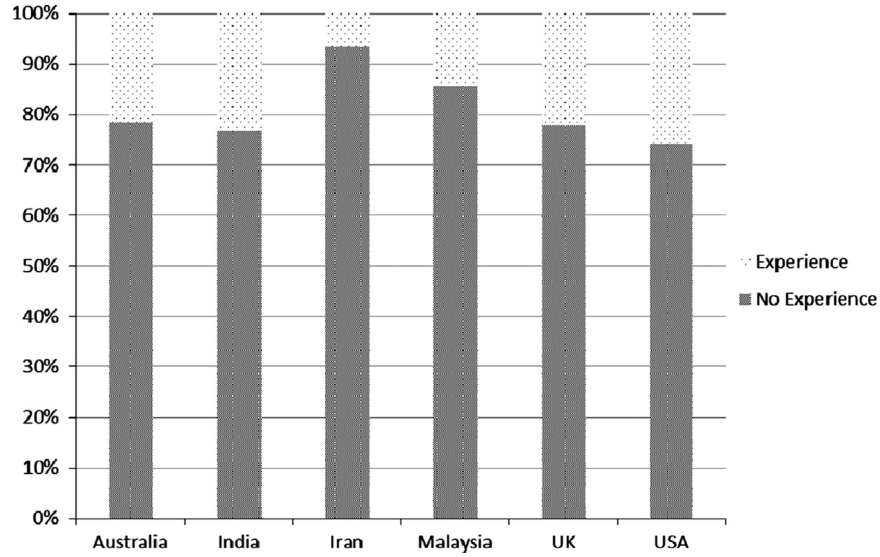

Fig. 16. Overall current experience by surveyed experts with existing national codes in earth building in their own countries.

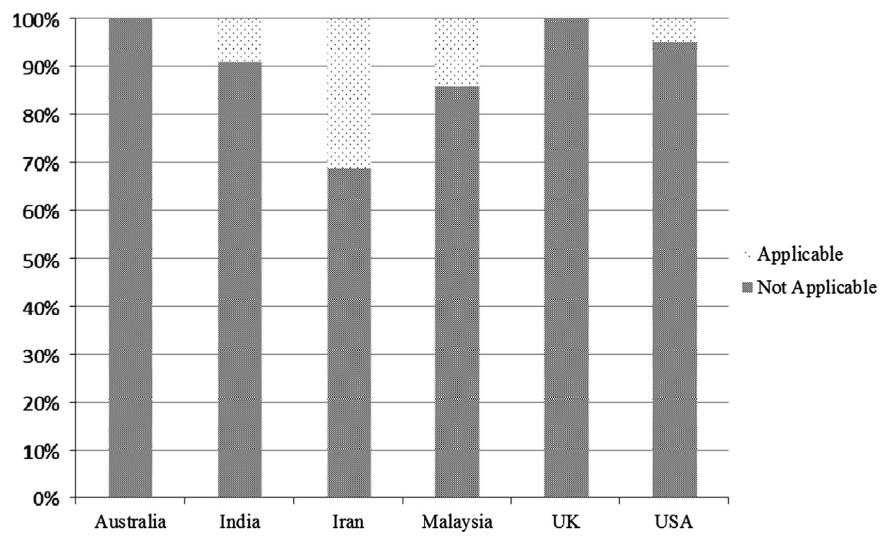

Fig. 17. Overall current ratings/scores assigned by surveyed experts for existing national codes of earth building.

architecture in current times. This can prove to be a disadvantage in the development of earth architecture and earth building in various countries.

Experts were asked: Have you completed training to become an accredited professional for any earth building existing national code? Based on the mean average, experts from the six surveyed countries consider that there is currently a lack of training courses to become an accredited professional. Experts believe that the current activities on earth architecture and training courses are very limited, reflecting the necessity to revolutionize earth architecture and earth buildings in order to liberate the high potential in this building sector. However, there are also experts who believe that training courses can increase knowledge on earth building between existing engineers, researchers and architects. Fig. 18 reflects the overall lack of earth architecture related training courses to become an accredited professional, although results show some activities undertaken by Australian, Iranian and Indian societies.

Based on an analysis of opinions about various aspects of "earth building construction tools" in earth architecture and earth building, experts seem to consider national codes in relation to "earth building construction tools" as very important in each country, yet awareness, experience, and applicability of existing national codes are very weak in regard to earth architecture and earth buildings in most countries. The main aim of amassing opinions and experiences on "earth building construction tools" is to determine the necessity to further develop high quality national codes. Furthermore, it is very important that these codes are recognized by various training courses in the mentioned countries, since training courses to become an accredited professional expert in earth architecture and earth building will assist the future of earth architecture and earth buildings. These responses suggested involving "earth building construction tools" as an important component in driving each country towards more earth building development. Historically, building owners did not use any earth building tools in the construction for creating earth buildings. The discrepancy between interest and involvement of earth building tools in construction emphasizes that the building industry is far more willing to participate in the production of earth buildings. The buildings need a national code to protect the existence of earth buildings in various countries. Earth building construction tools and national codes can help in the decision-making and

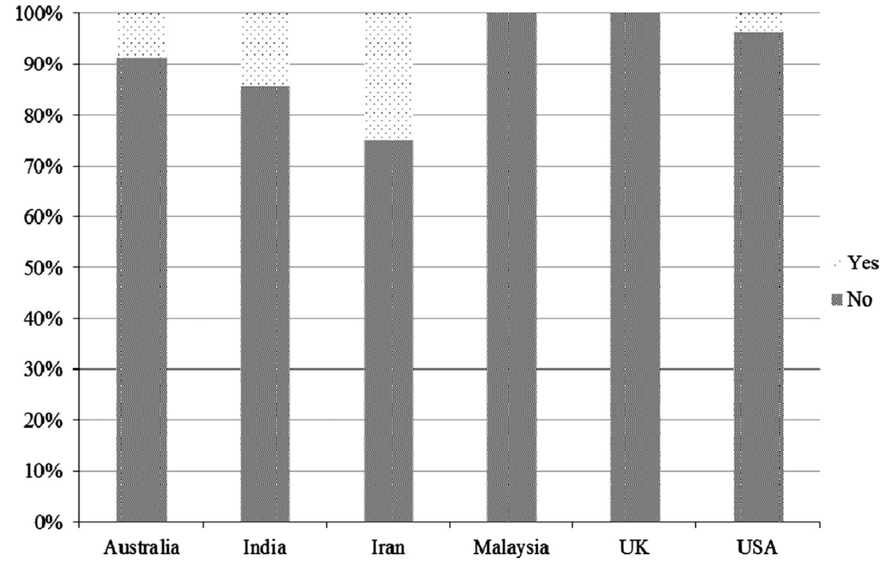

Fig. 18. Participation by respondents in accredited professional training for any existing national code on earth building (as of November 2012).

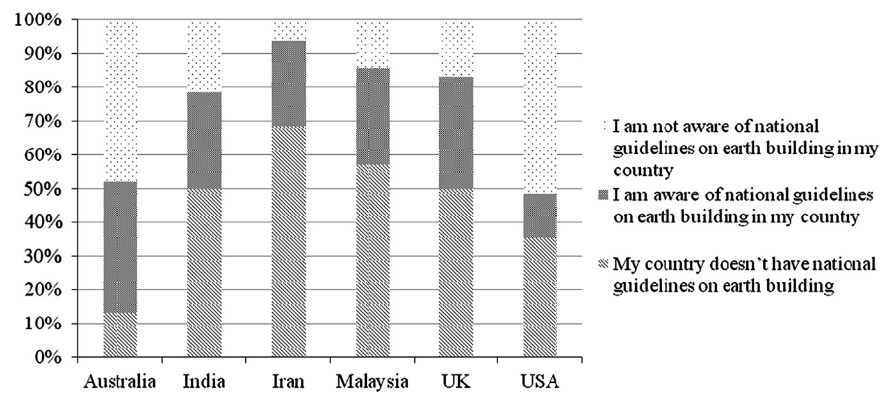

Fig. 19. Overall current awareness on national guidelines in the respective countries of the surveyed experts.

creation of various earth buildings of a national and international standard. It can be concluded that experts, in general, agree that the presence of national codes will increase the development of earth architecture and earth buildings in various countries. They agree that national guidelines can help engineers and architects in design and construction of high quality earth buildings. The shortage of training courses is a disadvantage in the development of earth architecture and earth buildings. In summary, the comparative analysis of experts' opinions about national codes and their related training courses shows that experts from all the surveyed countries generally have the same opinions on this topic. This signifies that experts from all the six surveyed countries have a similar understanding and regard about national codes and guidelines governing earth architecture and earth buildings. Therefore, experts need knowledge on "earth building construction tools" in design and construction of earth architecture and earth buildings in future.

4.4.3. Section 3

4.4.3.1. National guidelines and handbooks on earth buildings and earth architecture. This part evaluates national guidelines and handbooks on earth architecture and earth buildings and describes various aspects of national guidelines and their effects on the development of earth architecture in the six surveyed countries. The national guidelines and handbooks are very important in the development of earth architecture and earth buildings and are of vital assistance to architects and engineers in their design and construction.

4.4.3.2. National guidelines awareness. Next, the respondents were asked: Are you aware of national guidelines and handbooks covering earth building in your country? Most participants selected "I am not aware about national guideline" or "my country does not have any national guidelines". In general, low importance was attributed to guidelines and national codes in the surveyed countries, although a few experts selected "I am aware of national guidelines in my country", but unfortunately it is not a considerable percentage. Based on Fig. 19, an average of 28% of participants selected "I am not aware about national guidelines" signifying that many countries do not have a national guideline in earth architecture and earth buildings.

4.4.4. Section 4

4.4.4.1. National handbooks on earth buildings and earth architecture. This section evaluates national guidelines and handbooks on how Earth building applications use the tools and whether national guidelines were likely to seek formal certification.

4.4.4.2. National handbooks awareness. The next question wanted to determine: How important is it for the building industry to operate within a developed country in regard to promoting earth building and earth architecture? Participants selected, on an average, 22%, 14%, 6%, 14%, 0% and 16% as "extremely important", 30%, 64%, 44%, 58%, 26% and 10% as "very important", 30%, 14%, 44%, 28%, 40% and 30% as "important", and 8%, 6%, 6%, 0%, 5% and 20% as "slightly important" in Australia, India, Iran, Malaysia, UK and USA, respectively, as illustrated in Fig. 20. Based on the results, most surveyed experts agree that earth architecture and earth buildings are an important development in the building industry. They also agree that earth architecture can further develop in the building industry in their respective countries and that earth buildings have great potential as a building type.

4.4.4.3. Influence of a national guideline. Respondents were asked: To what extent do you think national guidelines would influence the building industry in a shift toward more earth building development in your country? Most experts agree that national guidelines are important in the development of earth architecture and earth buildings in their countries. Based on participants' results, 35% said national guideline are "very influential" in the building industry in regard to the creation of earth buildings, although 15% selected either "influential" or "slightly influential" as illustrated in Fig. 21. The results show the importance of national guidelines in the development of earth architecture and earth buildings. It is a fact that most experts in developed and developing countries agree with the formation of national guidelines in earth architecture and earth buildings, since earth buildings exist in both developing and developed countries.

4.4.4.4. Application of the earth building national code in each country. As an extension of the last question, respondents were asked: How likely is it that you will refer to national codes on earth buildings once it is officially released? Most experts would approve of the existence of a national guideline on earth architecture and earth buildings in their respective countries; furthermore few experts oppose the implementation of a national code. Based on the results, participants likelihood of referring to national codes on earth buildings was around 37% with "extremely likely", 27% with "very likely", 19% with "likely", however 6.4% selected "not likely" to use national codes on earth buildings, as illustrated in Fig. 22. Most experts approve of the existence of national guidelines to detail vital nuances for architects, engineers and contractors in the development of earth architecture and earth buildings based on local properties, limitations and conditions.

4.4.4.5. Intended use of national guidelines. Respondents were asked: If you are likely to use the national guideline on earth building in your country, how do you anticipate using it? Most experts selected various responses in this part, although this

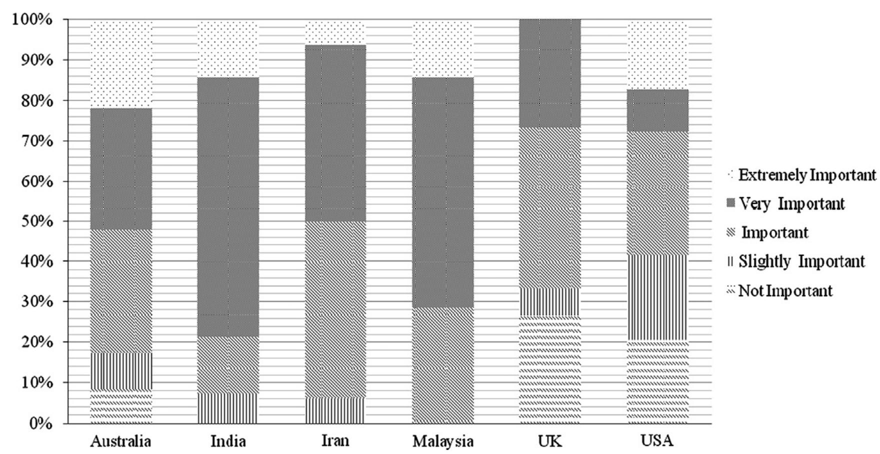

Fig. 20. Overall importance for the building industry to operate in a developed country in regard to promoting earth building and earth architecture in the six surveyed countries.

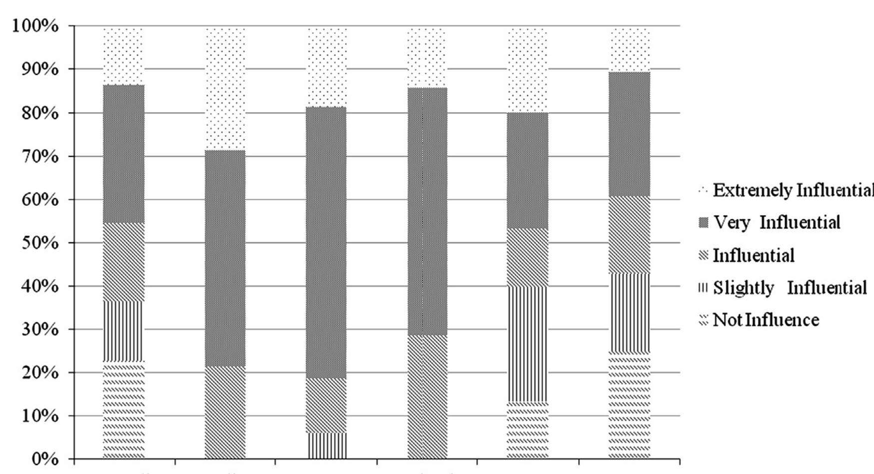

Fig. 21. Overall responses by experts on the perceived influence of national guidelines in a shift towards more earth building developments in their respective countries.

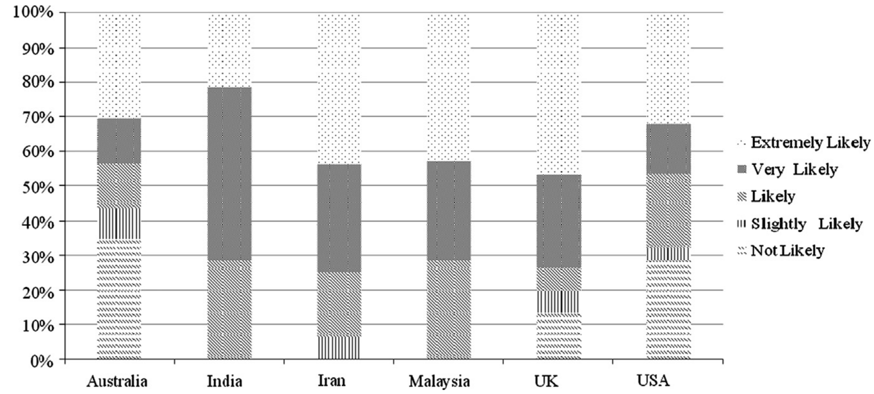

Fig. 22. Overall likelihood of respondents applying/implementing/referring to national codes once it is officially released.

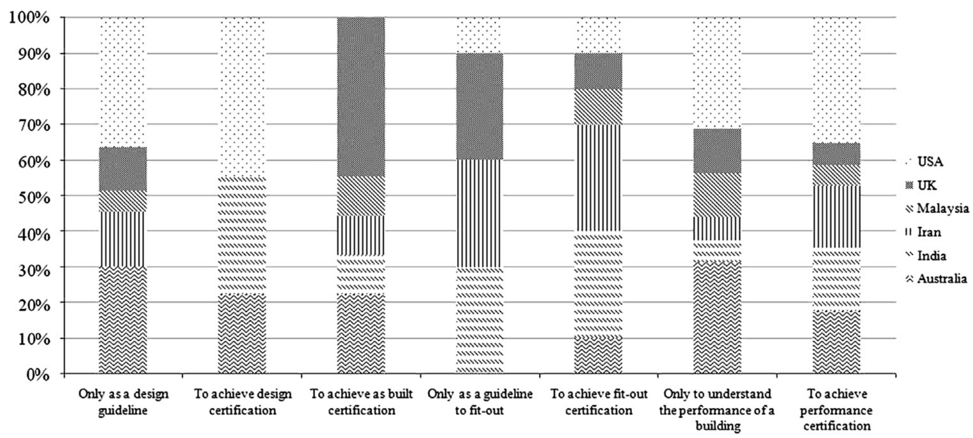

Fig. 23. Overall distribution on how respondents anticipate applying national guidelines.

question indicates the main objectives of experts in earth architecture and earth buildings in the six surveyed countries. Participating countries majority responses varied, such as American experts with "to achieve design certification", British experts with "to achieve building certification", Malaysian experts with "only to understand the performance of a building", Iranian and Indian experts with "only as a guideline to fit-out", and Australian experts with "only as a design guideline" as illustrated in Fig. 23. In this part, experts from across the six surveyed countries did not respond similarly. American and British experts valued the benefit of certification as a documentation of quality assurance, but Malaysian participants were more likely to use national guidelines as a tool to assess the performance of a building. In stark contrast to American and British experts, Iranian and Indian experts intend to use it as a guideline only. Australian experts would apply national guidelines as a design guideline in design and construction of future earth buildings in Australia. This question reflects the importance of national guidelines of earth architecture in the six surveyed countries and shows the main requirement of earth architecture in their respective countries.

4.4.4.6. Earth buildings training. As an extension of the previous question, respondents were asked: How likely is it that you will seek training to become an earth building accredited professional? Unfortunately, most experts were not aware of any professional training courses to become an accredited professional in earth architecture, despite the probability that such courses would increase the incidence of earth architecture in various countries. Based on the results, no definitive result can be concluded about the respondents and the requirement for earth building training. American and Australian experts selected "not likely" with more than 50%, but other countries selected "extremely likely" and "very likely" with almost 60%, as illustrated in Fig. 24. This signifies the demand for professional training courses to provide professional accreditation in earth architecture and earth buildings in Iran, India, Malaysia and UK. These courses can increase the number of skilled experts in earth architecture and earth buildings. In turn, such courses can assist to create a new century in communication between related institutes in architecture, engineering and earth architecture in close future.

4.4.4.7. Earth buildings certification. To gain an idea of the perceived significance of accreditation by experts, they were asked: How important is it that buildings in your country seek full earth building accreditation? Australia, India, Iran, Malaysia, UK and USA gave fluctuating responses; 24%, 20%, 37%, 29%, 13% and 20% with "important", 28%, 20%, 35%, 55%, 36% and 11% with "very important" and 22%, 50%, 24%, 13%, 14% and 23% with "extremely important", as illustrated in Fig. 25. Based on the participants' results, most participants said earth building certification is important for quality development of earth buildings and earth architecture in future. Earth building certification can increase the quality of earth architecture and earth buildings in practice. Experts from the six surveyed countries agree that earth buildings should receive certification, potentially increasing the quality and development of earth architecture and earth buildings.

4.4.4.8. Reasons for using national guidelines. Subsequently, reasons were sought as to why respondents would implement guidelines. They were asked: What would be your reasons for using national guidelines on earth building and earth architecture? Figs. 26–31

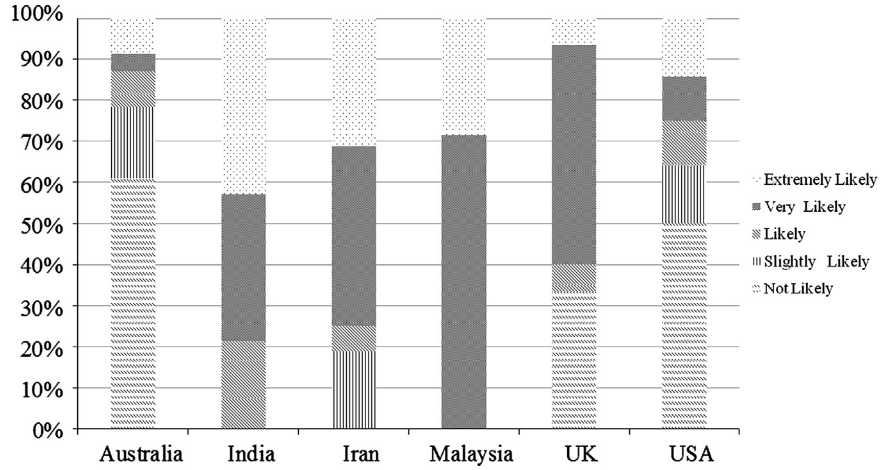

Fig. 24. Overall likelihood that respondents would seek training to become an earth building accredited professional given access to accredited training.

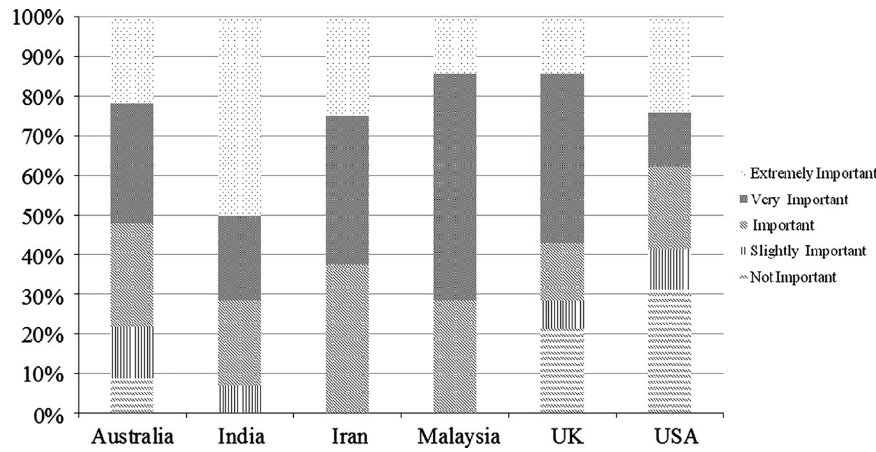

Fig. 25. Overall perceived importance by experts of accreditation of earth buildings.

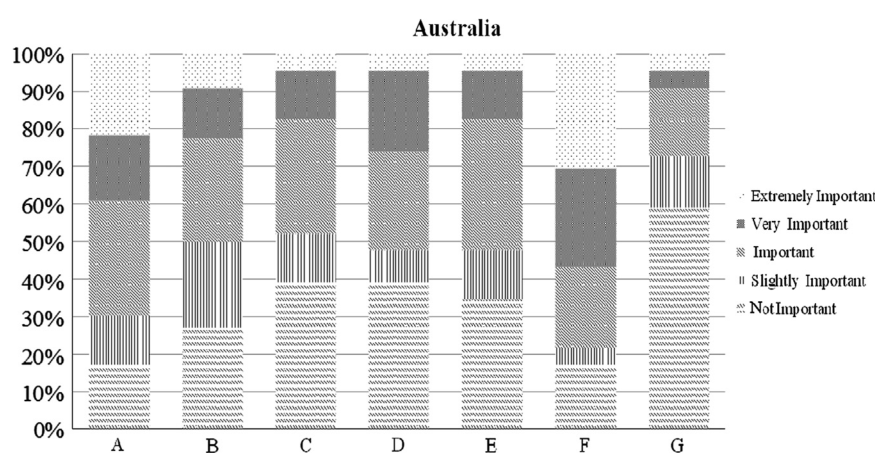

Fig. 26. Overall reasons respondents anticipate using national guidelines on earth building and earth architecture in Australia.

illustrate the most selected reasons why surveyed experts would use national guidelines on earth building and earth architecture. These reasons reflect the importance of national guidelines in the six surveyed countries and indicate their potential to solve or support these areas by implementing national guidelines.

This section investigated the importance of national guidelines in the development of earth architecture and earth buildings in the six surveyed countries. Established national guidelines can further support the development of earth architecture and earth buildings as a type of building industry on a number of levels in various countries. Most experts believed that their country needs a national guideline for various reasons that support earth architecture and earth building in one way or another, such as to achieve design certification, as a design guideline, or only as a guideline. The results reveal that most experts would make use of training courses to become an accredited professional, except for

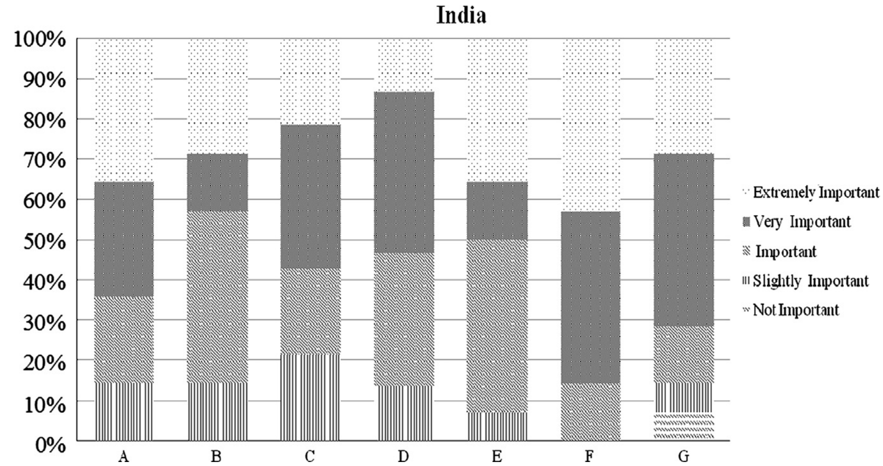

Fig. 27. Overall reasons respondents anticipate using national guidelines on earth building and earth architecture in India.

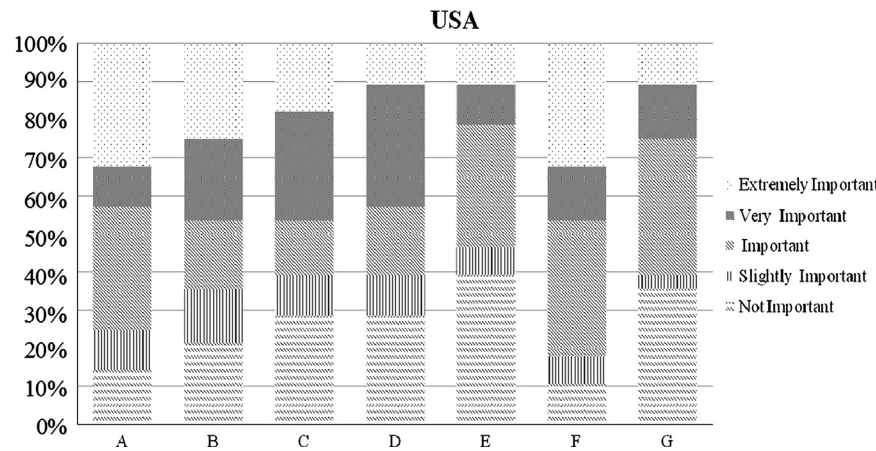

Fig. 28. Overall reasons respondents anticipate using national guidelines on earth building and earth architecture in USA.

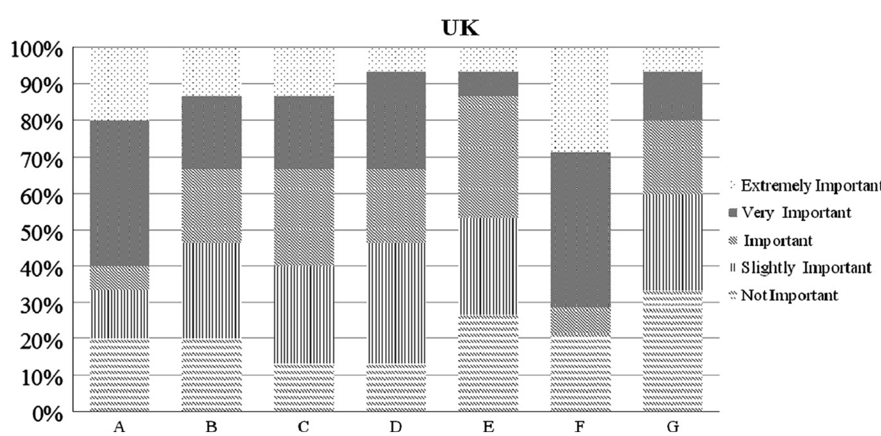

Fig. 29. Overall reasons respondents anticipate using national guidelines on earth building and earth architecture in UK.

American and Australian experts, reflecting the value of accredited professional programs in earth architecture and earth buildings. The experts agree that earth building certification can increase the quality and speed of development of earth architecture and earth buildings in future in the six surveyed countries. Anticipated use of national guidelines reveals the requirements of earth building experts in various countries. Guidelines can assist to solve existing gaps and requirements recognized by experts in future.

The respondents also mentioned that national guidelines are not the only tool, development or initiative that will be required to help the shift towards greater development of earth architecture and earth building. Implementation of national guidelines will need support assistance, such as rules, guidance, help and detailed information from the related international societies, the building ministry and governments to increase the development of earth architecture and earth building in each country. Experts recognize the necessity that earth buildings acquire national certification. Most experts anticipated “social and environmental responsibility to create vernacular buildings” as the main reason to use national guidelines in earth building and earth architecture. This result

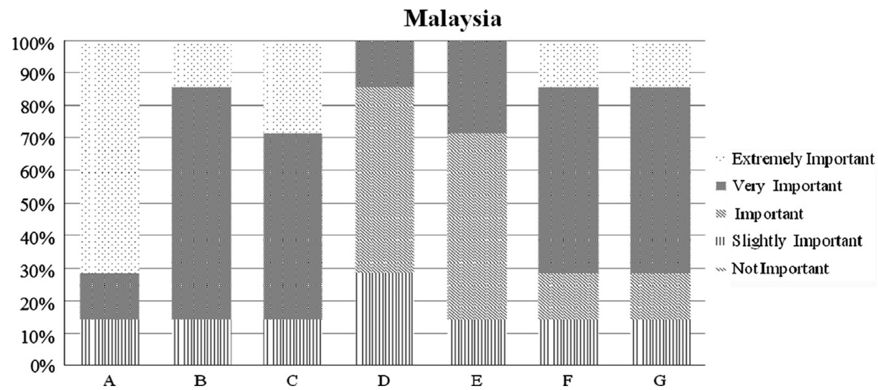

Fig. 30. Overall reasons respondents anticipate using national guidelines on earth building and earth architecture in Malaysia.

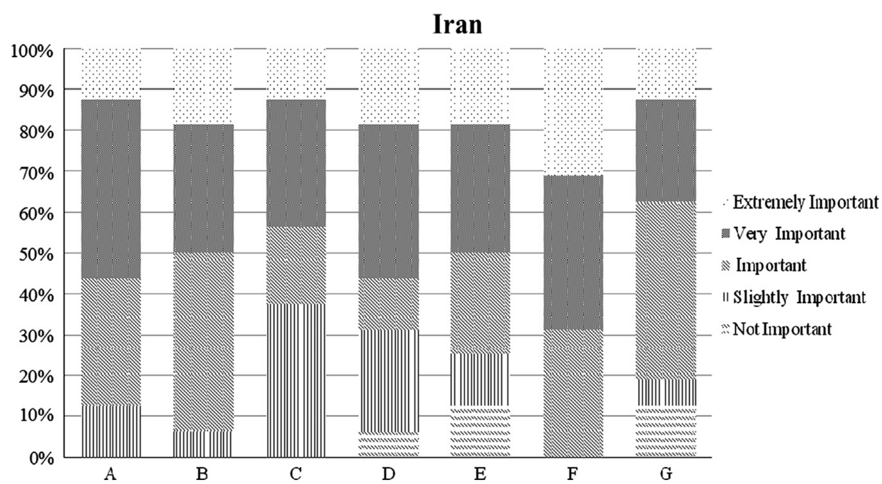

Fig. 31. Overall reasons respondents anticipate using national guidelines on earth building and earth architecture in Iran.

indicates an increasing social emphasis placed on earth architecture and earth buildings by USA, Malaysia, Iran, India, UK and Australia. The answers related to national guidelines from USA, Malaysia, Iran, India, UK and Australia affiliations were, on the whole, not extremely different. All the results emphasized the importance of national guidelines on earth buildings in each country. This emphasized a key difference between the six groups: USA and Australian experts seem to be better informed than the other countries, with the USA having built various types of earth buildings in the western United States 10 years ago. While they may not yet provide the level of national guidelines in earth building and earth architecture, or the continued training courses and seminars that many experts would want, the importance of certified earth building should increase in most countries.

4.4.5. Section 4

4.4.5.1. International Council on Monuments and Sites (ICOMOS). This section evaluates the role of the ICOMOS in earth architecture and earth buildings. The ICOMOS includes various branches in various countries, but, prior to delving further into this organization, it is important to clarify their role and significance in earth architecture. This section addresses the related questions.

4.4.5.2. International Council on Monuments and Sites Awareness. Respondents were asked: Are you aware of the ICOMOS in your country? The results show a high awareness of experts about ICOMOS, signifying the relevance of ICOMOS in future earth architecture and earth buildings plans. The ICOMOS is potentially the main center for increasing the activities of earth architecture and earth buildings in the future. Based on the results, the building industry has a high level of awareness of the ICOMOS with 100% of respondents from Australia, Iran, UK and USA. However, many Indian and Malaysian respondents were unaware of the ICOMOS; in the case of Malaysia respondents, it is most likely because there is no ICOMOS branch in their country as illustrated in Fig. 32.

4.4.5.3. International Council on Monuments and Sites Approach. Respondents were asked to consider: How appropriate is the approach of the ICOMOS in the establishment of a national society on earth building in your country? About 51% of all respondents selected “appropriate”, indicating that they approved the approach of the ICOMOS in establishing a national society on earth building and earth architecture in the mentioned countries, as illustrated in Fig. 33; however, they also mentioned that more facilities from national experts, governments and related organizations are necessary. Based on these results, ICOMOS perhaps has a greater potential to assist in the protection and organization of earth architecture and their plans in future. Most experts communicated that ICOMOS has a great potential for the future of earth architecture and earth buildings. ICOMOS can further develop their activities around the world since most countries do not yet have an ICOMOS branch.

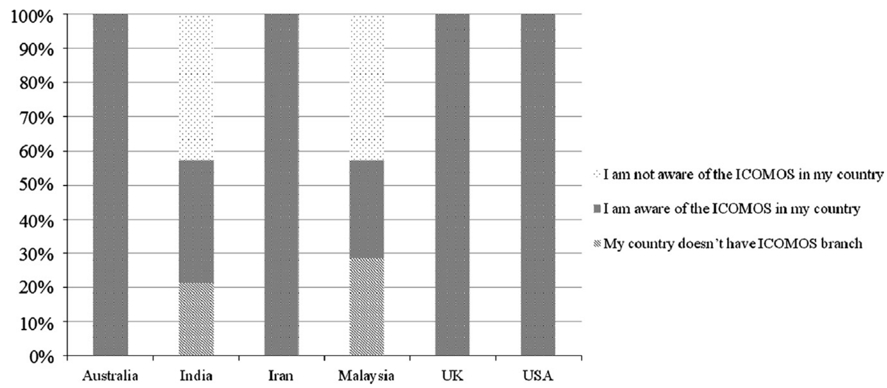

Fig. 32. Overall current awareness of the ICOMOS by respondents in the six surveyed countries.

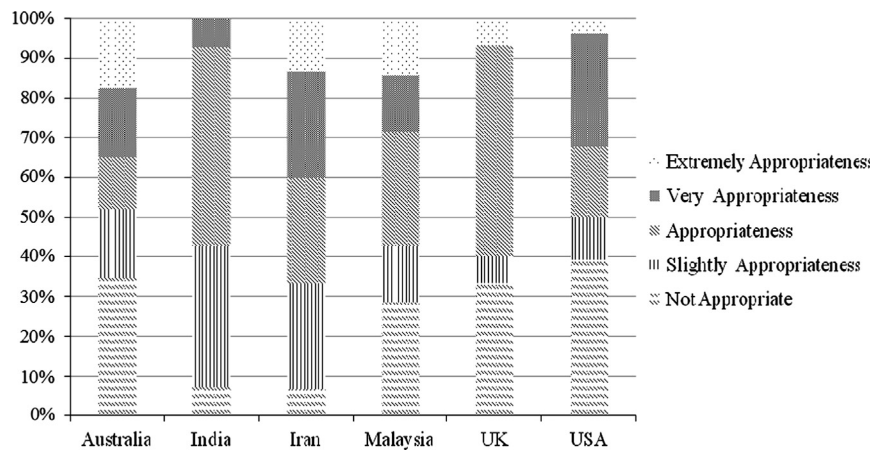

Fig. 33. Overall perceived appropriateness of the ICOMOS by respondents in the establishment of a national society on earth building in the six surveyed countries.

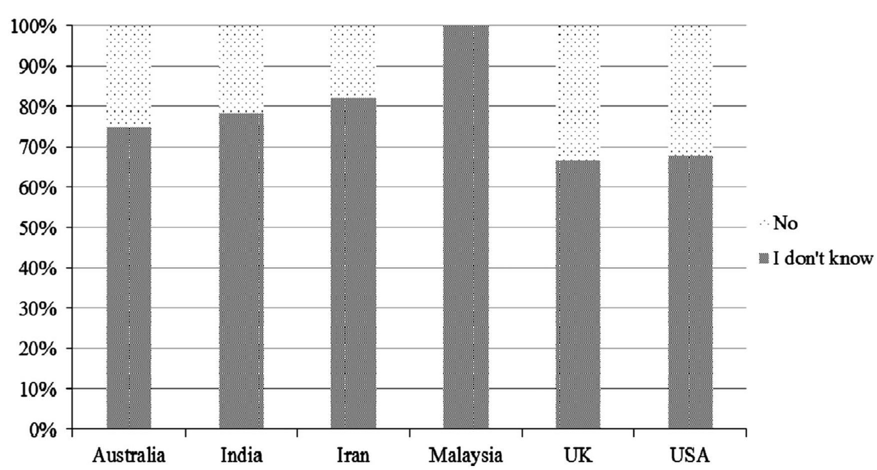

Fig. 34. The presence of reason for experts' selection of the appropriateness of the approach of the ICOMOS in the establishment of a national society for earth building and earth architecture in each country.

As an extension of the previous question, respondents were asked: Do you have any reason for your selection of the appropriateness of the ICOMOS in the establishment of a national society on earth building in your country? Most participants selected "I do not know" with 73% and "No" with 27%, reflecting minimal information and understanding of the ICOMOS as illustrated in Fig. 34. This result suggests that the ICOMOS needs to output more information on its activities and programs and ensure that the information reaches experts, in order for them to gain enough knowledge about the organization to find an opinion on the development of a national society on earth architecture and earth buildings in their countries.

4.4.5.4. International Council on Monuments and Sites influence. The next question addressed to survey participants was: To what extent do you think the ICOMOS would influence the building industry in a shift toward more earth building development? Developed countries almost agree that the ICOMOS would have a low influence on earth architecture in a shift toward more earth building development and, accordingly, developing countries

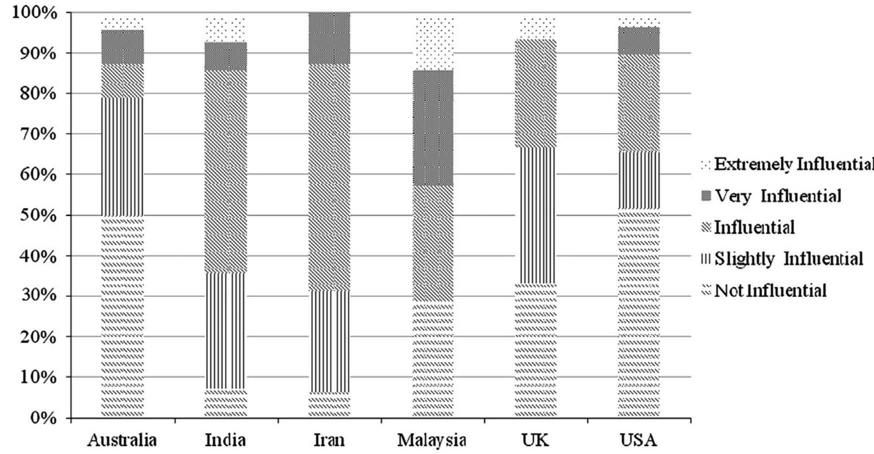

Fig. 35. Overall perceptions that the ICOMOS will influence the building industry in a shift toward more earth architecture and earth building development.

agree that the ICOMOS would have a high influence on earth architecture in a shift toward more earth building development. Experts selected various responses such as 30% with "influential", 16% with "very influential" and 6.7% with "extremely influential" in a shift toward more earth architecture and earth buildings, as illustrated in Fig. 35. The results describe the significance of the ICOMOS, but the ICOMOS needs more support from governments and related organizations in various countries.

An attempt to determine the significance of ICOMOS in the development of earth architecture and earth buildings in the six surveyed countries was made. It was ascertained that most countries know about ICOMOS except for a few (such as Malaysia), suggesting that there is a need to establish an ICOMOS branch in these countries. Based on the results, some experts would consider it appropriate for the ICOMOS to establish a national society in these surveyed countries where none currently exists, but it needs more support by governments and related organizations. Furthermore, the ICOMOS needs to elaborate further on their objectives, since most experts were not sufficiently informed to base an opinion on the appropriateness of the ICOMOS to establish a national society in their country. Experts have disparate opinions on the role of the ICOMOS and its influence on the building industry in a shift towards more earth building development, in particular, developed countries (who did not agree with the current level of ICOMOS) opposed developing countries (who agreed with the current level). It is important to note that not only will the ICOMOS be required to become further involved in the development of earth architecture and earth buildings, the building industry, related organizations and governments will also need to contribute a greater commitment. Results show that participants think that the ICOMOS can influence the building industry in a shift towards more earth building development, but only a "low influence" is expected. What then are the barriers inhibiting end-users from fully embracing the ICOMOS and earth buildings?

4.4.6. Section 5

4.4.6.1. Triggers, drivers, obstacles and reasons for earth building and earth architecture. A correct understanding of these factors needs an analysis of various elements of earth architecture. Therefore, this section investigates participants' perceptions on the triggers, drivers, obstacles and reasons prompting earth building and earth architecture. Identifying such factors is the first step towards solving the various problems inherent with earth architecture.

4.4.6.2. Trigger(s) for Earth buildings and Earth architecture. Participants were asked: In your experience, who triggers earth building and earth architecture in the first place? Most experts selected "client", "architects" and "engineers" as the main triggers of earth architecture and earth building in the six surveyed countries. The "client" was seen to be the main trigger initiating earth building and earth architecture with 63% of the participants identifying them as such, while the "architect" was identified 41% of the time and "engineers" with 29%. Fig. 36 illustrates the main triggers and their frequency. Although the main trigger was identified as the "client" who took the initiative to commence an earth building project, "architects" and "engineers" mentioned that their role had a slightly greater influence than the client.

After identifying the triggers, participants were next asked: In your opinion who should be the main driver for earth building and earth architecture? Although the "client" was seen to be a significant driver, the most important driver was to have "an integrated process where responsibility is shared" as illustrated in Fig. 37. This shows that "an integrated process where responsibility is shared" is very important as a main driver in the development of earth architecture and earth buildings in the six surveyed countries, because this can create an integrated process for a very good future in earth architecture and earth buildings. The main driver is also important to increase the speed of the development of earth architecture and earth buildings.

4.4.6.3. Trigger stage for earth architecture and earth buildings. To add further detail to the previous question, participants were asked: At what stage of the building process is earth architecture most likely triggered? Most experts selected "pre-design" as the main stage of the building process in earth architecture and earth buildings. They believed that the "pre-design" step is an important step as a trigger phase in the building process of earth architecture and earth buildings in practice. Experts know about the importance of design steps as a trigger phase in the development of earth architecture and earth building. Experts overall recorded "pre-design" with 49%, and "preliminary inquiries" with 35%, as illustrated in Fig. 38.

4.4.6.4. Drivers for Earth buildings and Earth architecture. Experts were asked: What do you think are the main drivers for earth building? In response to this, Iranian experts selected material performance as a main factor, signifying the value of materials in Iran's earth architecture. Malaysian and British experts voted "rising energy costs" because this is a main factor in

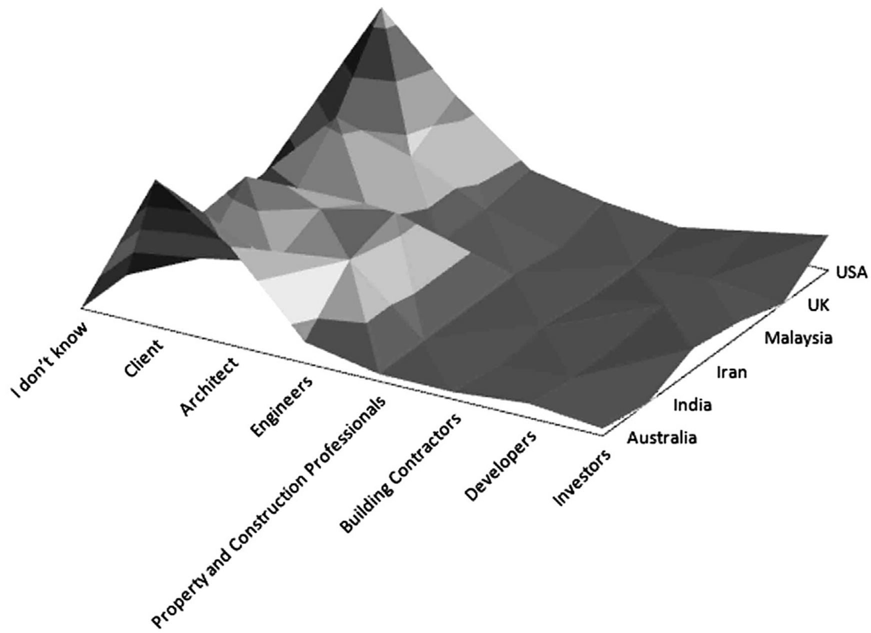

Fig. 36. Overall responses identifying who triggers earth architecture and earth building.

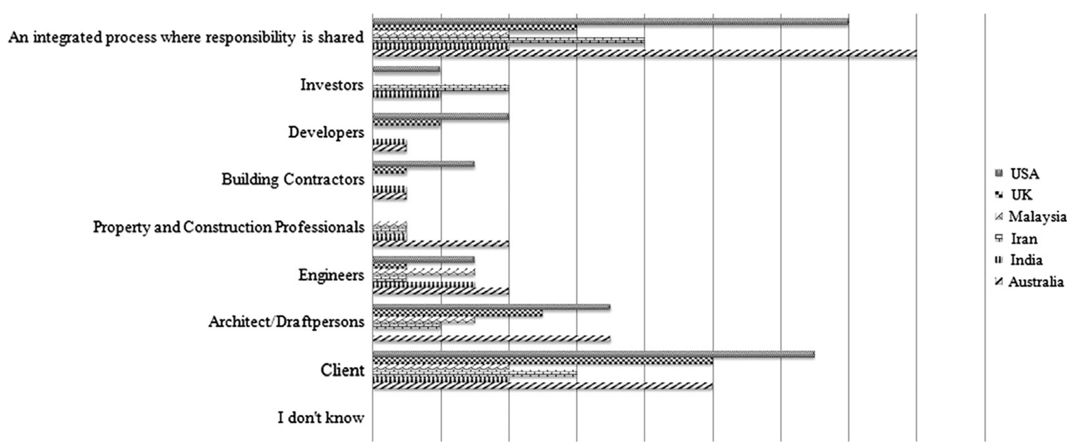

Fig. 37. Overall opinions of who must be the main driver(s) for earth architecture and earth building.

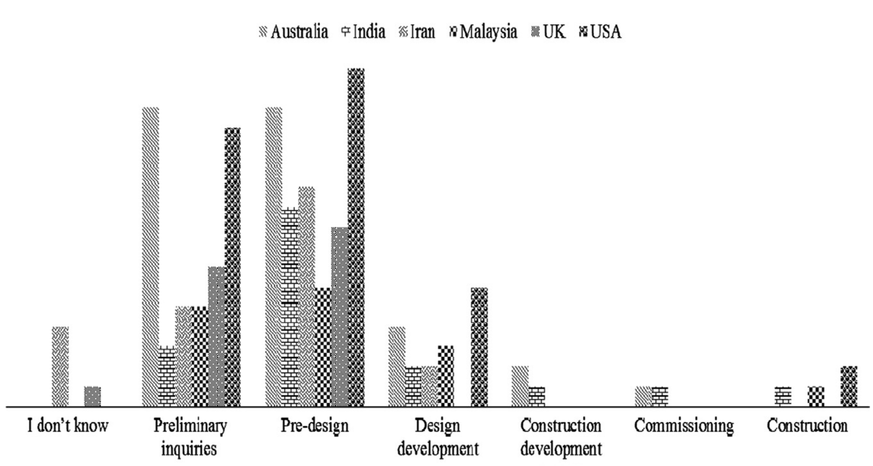

Fig. 38. Overall distribution of stages of the building process that earth building and earth architecture are most likely triggered.

the building industry. American, Indian and Australian experts agreed that "environmental conditions" are a main driver in the future development of earth architecture and earth buildings, signifying the growing interest in the application of natural materials as an environmental protection measure, as illustrated in Fig. 39.

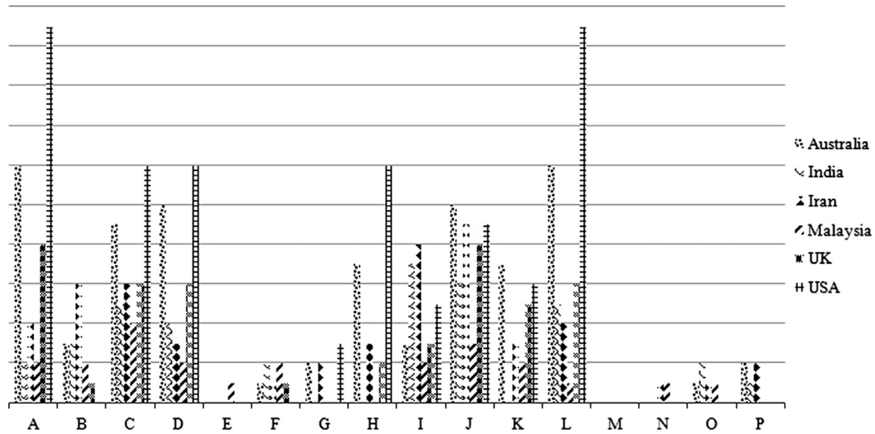

Fig. 39. Drivers for earth architecture and earth buildings.

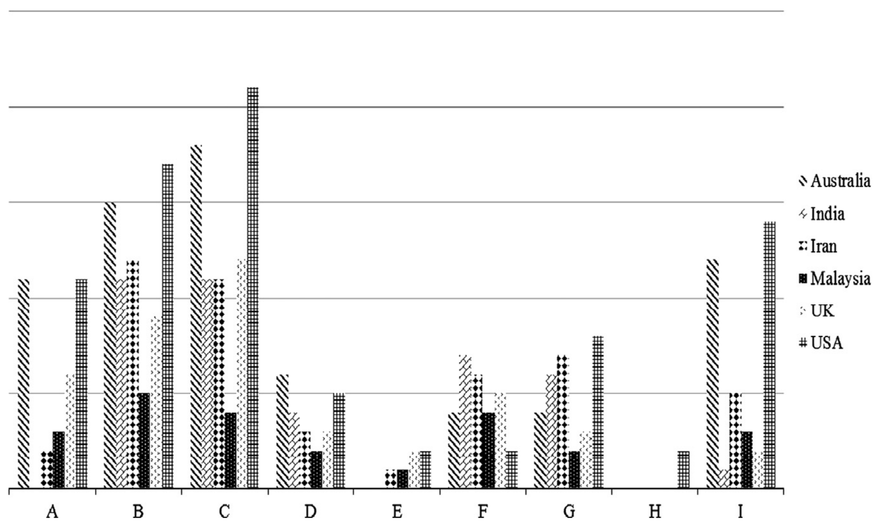

Fig. 40. Overall distribution of obstacles inhibiting earth architecture and earth buildings.

4.4.6.5. Obstacles for Earth architecture and Earth buildings. In order to identify inhibiting factors, experts were asked: What are the obstacles to earth building? Iranian and Malaysian experts believed that a lack of education is an obstacle to earth architecture and earth building in their countries, while American, British, Australian and Indian experts selected lack of awareness as an obstacle, as illustrated in Fig. 40. These results show the importance of education and awareness in the future of earth architecture and earth buildings in practice. The "different accounting methods" with 1.8% and "Payback periods" with 0% were the lowest perceived barriers in earth architecture and earth buildings. Related organizations and societies need more discussion with various universities and training centers in order to increase awareness of earth architecture and modern theories and technologies on earth architecture between experts and researchers.

4.4.6.6. Reasons for involvement in Earth architecture and Earth building. Next, the survey aimed to determine: What are your reasons for being involved with earth building? Iranian, Indian and Malaysian experts selected "Achieving lower life-cycle costs" as the main reason for their involvement in earth architecture and earth buildings, while American, British and Australian experts believed "being part of an industry that values the environment" as the main reason for involvement in earth architecture and earth buildings, as illustrated in Fig. 41. This shows the different ideas between developed countries and developing countries driving their involvement in earth architecture.

4.4.6.7. Economic/benefits reasons for Earth architecture and Earth building. Experts were next asked: What do you believe are the economic reasons/benefits of earth building? Most experts consider "lower lifetime costs" as the most important economic reason in earth architecture and earth buildings, as illustrated in Fig. 42, although "lower operating costs" were identified as the second economic reason in the future of earth architecture and earth buildings. "Increase staff productivity and retention" shows a low significance amongst the economic reasons in earth architecture and earth buildings. These results show the significance of various economic factors in earth architecture and earth buildings in the building industry's future and identify possible areas where costs can be significantly reduced.

4.4.6.8. Environmental reasons for earth architecture and earth buildings. Environmental motives are also always a consideration, therefore, experts were asked: What do you believe are the environmental reasons/benefits of earth building and earth architecture? Most experts selected "Protection of the environment" as the main environmental reason for earth architecture and earth buildings, signifying the importance of earth architecture in our environmental future and the potential it has to reduce cement

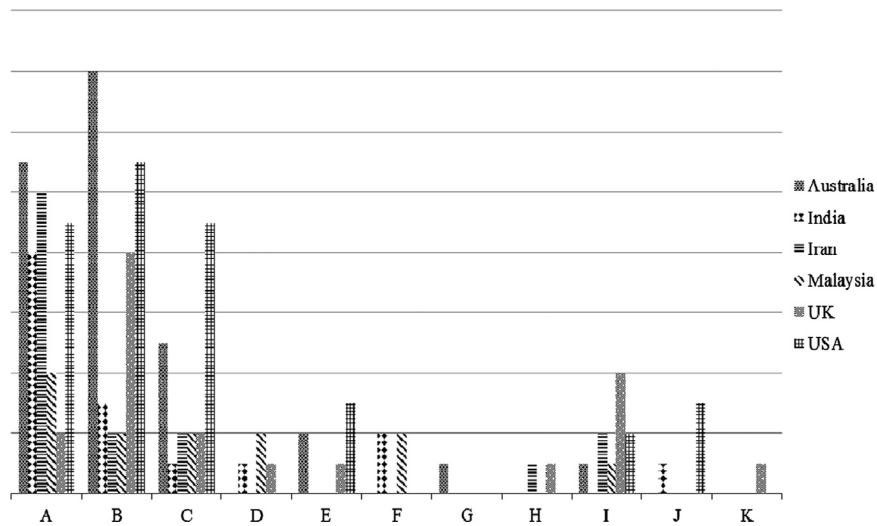

Fig. 41. Identified reasons for being involved with earth architecture and earth buildings.

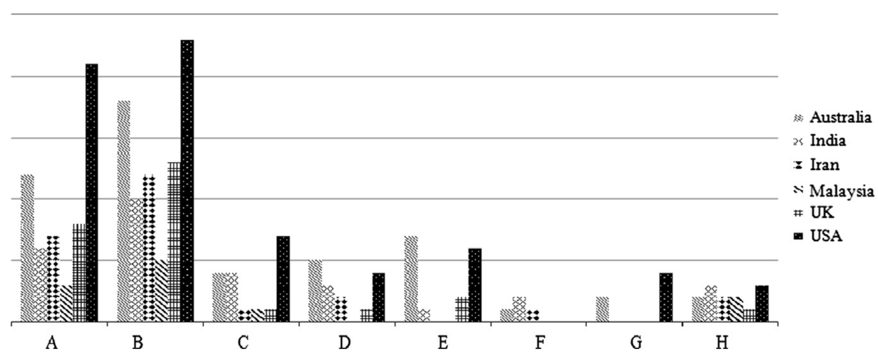

Fig. 42. The distribution of economic reasons supporting earth architecture and earth building.

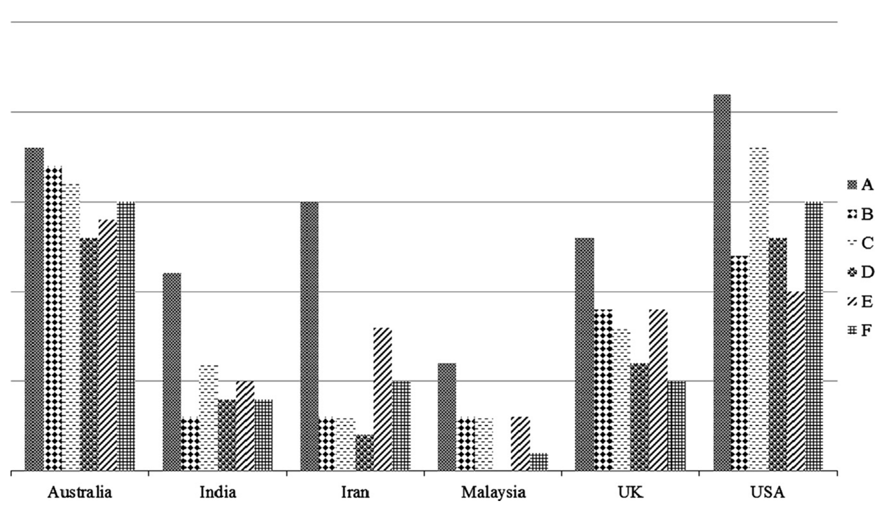

Fig. 43. Distribution of environmental reasons for earth architecture and earth buildings.

USAge and thus reduce CO_2 production. Other options selected as environmental reasons in earth architecture and earth building were "Minimizing the ecological impact of buildings", "Waste reduction", and "Reducing climate change and emissions", as illustrated in Fig. 43.

4.4.6.9. Social reasons for Earth architecture and Earth buildings. Further analysis aimed to investigate another outlook, therefore experts were asked: What do you believe are the social reasons/benefits of earth building? Most experts believe "Moral imperative of being 'sustainable'" as the main social reason in the development of earth architecture and earth buildings as illustrated in Fig. 44. Clearly, the sustainability of earth architecture and earth buildings proves to be an appealing future prospect to experts. The developed and developing countries surveyed all agree with the importance of earth

architecture and earth buildings in regard to their sustainable future.

Based on the experience of participants, the client, architects and engineers were considered to be the most important persons driving earth architecture and earth buildings. It is clearly evident why an earth building must be built to the user's requirements, however, they may not have the related knowledge to propose earth buildings and earth architecture items in their aims. However, evaluation of this item asked respondents a related question, namely who "must" be the main driver for earth architecture and earth buildings and the results showed "an integrated process where responsibility is shared" selected. Earth architecture and its future are so important in the building industry for a number of reasons. To ensure its future growth and development, various drivers, triggers, obstacles and economic/social/environmental reasons need to be identified. This part ascertains clients, architects and engineers as main triggers of earth architecture, although the foremost trigger are the clients who will live in these buildings. Earth architecture must be considered in the pre-design stage of the building process, as a main step in the design of earth buildings in future projects. Rising energy costs is a main driver in the development of earth architecture in the UK and Malaysia, and this is a factor that must be considered by the related organizations in these countries. Environmental conditions appear to be the main driver in the development of earth architecture in the USA, Australia, Iran and India. Development of earth architecture and earth buildings needs to be supported with more educational programs and awareness on various aspects of earth architecture and earth building, such as seminars, workshops, conferences, publications, TV programs and academic degrees on earth architecture. Achieving lower life-cycle costs is a main reason of most experts in developing countries, while being part of an industry that values the environment is the main reason of most experts in the developed countries. The survey revealed different reasons by our experts for their involvement in earth architecture and its development, based on the development of their country. This result shows the importance of cost and financial supports in the building industry. Most countries are already undertaking various projects on sustainable building indicating that the significance of earth architecture, the moral obligation of being sustainable, and sustainable development are becoming more recognized. If governments and related societies support earth architecture and earth buildings, then sustainable development in these countries will prosper. In addition to being an environmentally friendly and sustainable option, earth architecture is also in practice an economically undemanding long-term preference (Tables 3–9).

4.4.7. Section 6

4.4.7.1. Technical information on Earth architecture and Earth buildings. This section uses regression analysis to investigate effective parameters of earth architecture and earth buildings for each country separately. The results of these equations assist to determine the significance and relevance of various factors, thus assisting in crucial decision making in the development of earth architecture and earth buildings in the mentioned countries in future. Regression analyses were run in part three to find a relationship between current statuses of earth architecture based on the expert's opinions, in order to anticipate the future of earth architecture. Multiple regressions were used in these analyses to

Table 3
Reasons for using national guidelines in earth building and earth architecture.

	Reason	Option
1	Being able to assess the environmental impact of buildings	A
2	Building comparisons at a national level	B
3	Building comparisons at an international level	C
4	Promotional purposes	D
5	To use the information for company sustainability reporting	E
6	Social and environmental responsibility to create vernacular buildings	F
7	To monitor earth building and architecture growth within a country	G

Table 4
Identified drivers for earth architecture and earth building.

	Drivers	Option
1	Rising energy costs	A
2	Government regulation	B
3	Lower life-cycle costs	C
4	Client demand	D
5	Independent rating system	E
6	Government rating systems	F
7	Competitive advantage	G
8	Superior performance	H
9	Structural conditions	I
10	Materials performance	J
11	Increased education	K
12	Environmental conditions	L
13	Attraction and retention of staff	M
14	Increased emphasis on productivity	N
15	International trends show it is smart business	L
16	Disruptive/enabling technology	O
17	Other(s)	P

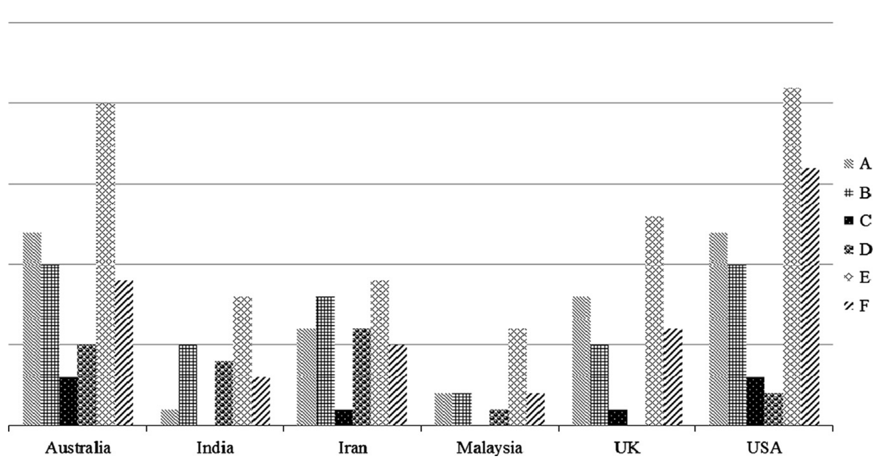

Fig. 44. Perceived social reasons/benefits of earth architecture and earth buildings.

Table 5
Identified obstacles inhibiting earth architecture and earth buildings.

	Definition	Option
1	Perceived higher upfront costs	A
2	Lack of education	B
3	Lack of awareness	C
4	No fiscal incentive	D
5	Different accounting methods	E
6	No coordination	F
7	Politics	G
8	Payback periods	H
9	Education of 'non sustainable' people	I
10	Other(s)	J

Table 6
Identified reasons for being involved in earth architecture and earth building.

	Definition	Option
1	Achieving lower life-cycle costs	A
2	Being part of an industry that values the environment	B
3	I am not involved	C
4	Contract requirement (e.g. government tenders)	D
5	Expanding my business with 'sustainable' building clients	E
6	Benefit from publicity	F
7	Triple bottom line reporting attraction	G
8	Retention of talent	H
9	Vernacular product information	I
10	Awards for earth building	J
11	Higher return on investment on resale	K

Table 7
Identified economic reasons for earth architecture and earth building.

	Definition	Option
1	Lower operating costs	A
2	Lower lifetime costs	B
3	Higher building value	C
4	Enhanced marketability	D
5	Helping to transform the market	E
6	Increase staff productivity and retention	F
7	Higher return on investment	G
8	Reduced liability and risk	H

Table 8
Key environmental reasons for earth architecture and earth buildings.

	Definition	Option
1	Protection of the environment	A
2	Reducing climate change and emissions	B
3	Minimizing ecological impact of buildings	C
4	Scarcity of natural resources	D
5	Improving indoor environment quality	E
6	Waste reduction	F

Table 9
Key social reasons/benefits for earth architecture and earth buildings.

	Definition	Option
1	Greater health and well-being	A
2	Improved learning and healing environments	B
3	Tenant productivity	C
4	Support for my country's economy	D
5	Moral imperative of being 'sustainable'	E
6	Aesthetically pleasing	F

predict one dependent variable by investigating two or more independent variables. Table 10 has shown effective parameters in earth architecture and earth buildings.

An analysis of experts' opinions on characteristic earth architecture is shown in Fig. 45. Based on the mean average, it shows that "recovery cost" and "maintenance cost" present the main cost saving factors in the development of earth architecture and earth buildings. "Recovery cost" presents the most noticeable parameter of cost saving in earth architecture features.

Fig. 46 shows the importance of various materials in earth buildings. It shows that "clay" and "sand" are the main materials used in earth buildings while "straw", "cement", "emulsion oil", "rice husk", "flyash", "lime", "nano-materials" and "waste materials" can be used as soil stabilizers, although experts believe that the significance of "POFA" (Palm Oil Fuel Ash) is negligible in earth materials.

Relative to the mean average, "sustainability" appears to be a main environmental parameter of earth architecture and earth buildings and "less pollution" was selected as the second main necessary parameter in regard to the future of earth buildings, as illustrated in Fig. 47.

There are six types of construction techniques applied in the surveyed earth buildings. Based on the mean average, it shows that experts consider "rammed earth wall" as the best construction technique among other techniques in earth buildings. The second best construction technique is the "adobe wall" in earth buildings. It is clear that most experts agree that the six construction techniques can be used in various applications of earth buildings as illustrated in Fig. 48.

The experts believe that earth buildings can be used in various climatic conditions, but based on the mean average, they emphasize that "Desert" is the best condition for earth architecture and earth buildings, as illustrated in Fig. 49.

Fig. 50 shows the significance of productivity gains of earth architecture and earth buildings using various parameters. It shows that "user satisfaction" is a main parameter in productivity gains of earth architecture and earth buildings; however, all the parameters are considered important by experts in the current status and future of earth architecture and earth buildings.

Earth buildings use various architectural styles in practice and there are eight architectural styles in the surveyed earth buildings. Experts believe that earth architecture has similarities with vernacular architecture, as illustrated in Fig. 51. Apparently, experts have different opinions about architectural styles of earth buildings, because the mean average does not significantly vary in this comparative analysis. It shows that, out of the eight recognized architectural styles used in earth buildings in the six surveyed countries, most experts agree that vernacular architecture was the most often applied rather than other architectural styles in most projects. Based on the mean average, experts believe that various architectural styles can be applied to earth buildings, such as neo-vernacular, corporate modern, post modern, modern, early modern, Persian, and Islamic.

Experts believe that earth architecture has a wide applicability for various projects. Earth architecture can be used in various applications as shown in Fig. 52. Buildings are the most common application in earth architecture, but the mean average shows that experts believe earth architecture can be used in other applications such as cities, water retainment, modified earth, excavations, platforms, terraces, earth retainment, shaped hills, and mounds.

4.4.7.2. Multiple regression analysis. Multiple regression analysis was used to predict the future of earth building and earth architecture by using the effective parameters (cost saving, materials, environmental, construction techniques, climate conditions, productivity

Table 10
Effective parameters in earth architecture and earth buildings.

	Parameter (s)	Items
1	Cost saving	(A1) Energy effacing, (A2) maintenance cost, (A3) material cost, (A4) construction cost, (A5) recovery cost
2	Materials	(B1) Clay, (B2) sand, (B3) straw, (B4) cement, (B5) emulsion oil, (B6) rice husk, (B7) palm oil fuel ash (POFA), (B8) flyash, (B9) lime, (B10) nano-materials
3	Environmental	(C1) Sustainability, (C2) less pollution, (C3) to flight global warming, (C4) waste minimization, (C5) minimized site impact
4	Construction techniques	(D1) Rammed earth wall, (D2) adobe wall, (D3) cob, (D4) wattle and daub, (D5) poured earth, (D6) extruded earth
5	Climate conditions	(E1) Desert, (E2) alpine, (E3) mild temperate, (E4) cold temperate, (E5) warm temperate, (E6) hot temperate, (E7) subtropical, (E8) tropical
6	Productivity gains	(F1) Reduced health risk, (F2) reduced safety risk, (F3) less claims made on health costs, (F4) Boosts creativity, (F5) higher morale, (F6) improved indoor air quality, (F7) user satisfaction, (F8) users have more control over their environment
7	Architectural styles	(G1) Islamic, (G2) Persian, (G3) early modern, (G4) modern, (G5) post modern, (G6) corporate modern, (G7) vernacular, (G8) neo-vernacular
8	Applications	(H1) Building, (H2) mounds, (H3) shaped hills, (H4) Earth retained, (H5) terraces, H6) platforms, (H7) excavations, (H8) modified earth, (H9) water retained, (H10) cities
9	Overall development	(Q18) Overall, the service has excellent quality. (Q19) The service quality provided by this website matches my expectations. (Q20) This website's service offerings are very competitive

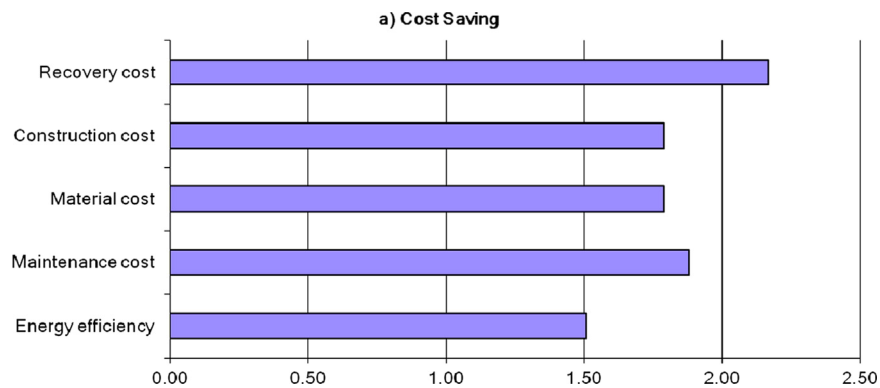

Fig. 45. Regression analysis results of costs involved in earth architecture and earth building.

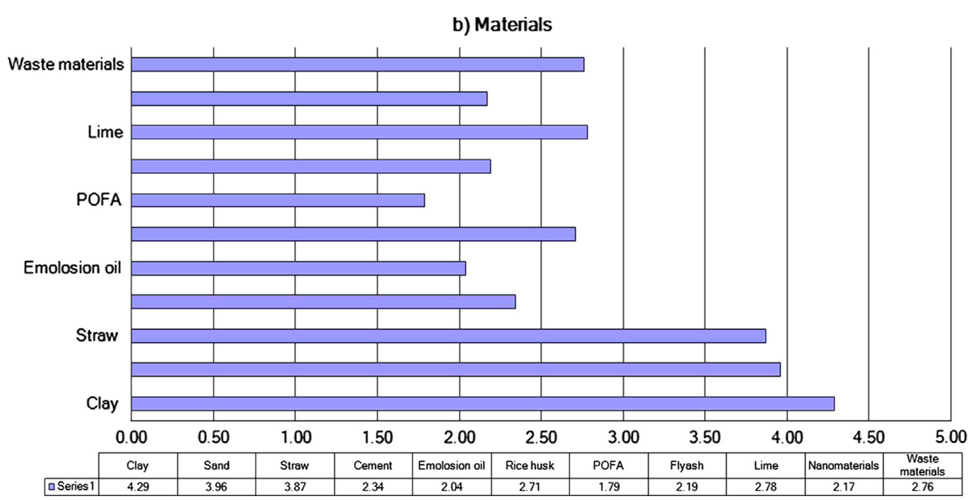

Fig. 46. Materials analysis in earth architecture and earth building.

gains, architectural styles, and applications) as the independent variables. The multiple regression analysis determines the relationship between the independent variables and the dependent variable. The multiple regression models applied is:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_kX_k=\beta_0+\sum_{i=1}^{i=k}\beta_iX_i$$

where Y is the dependent variable (predicted by regression model), k is the number of independent variables, X_i (i=1,2,…,k) is the ith independent variable from a total set of k variables, β_i (i=1,2,…,k) is the ith coefficient corresponding to X_i, β_0 is the intercept (or constant), i =1,2,…,k and independent variables' indices. Where the number of the independent variables in this case is five, therefore the regression equation is the following:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5$$

According to the research methodology, the multiple regression analysis steps involve the following:

1. Setup hypotheses:
   - H_0 (null hypothesis): $\beta_i \neq 0$.
     The independent variable, X_i, is not important for predicting the dependent variable (Y).

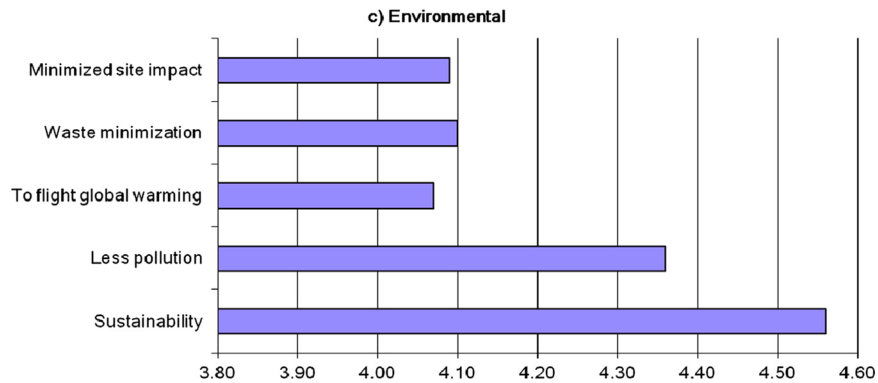

Fig. 47. Environmental analysis in earth architecture and earth buildings.

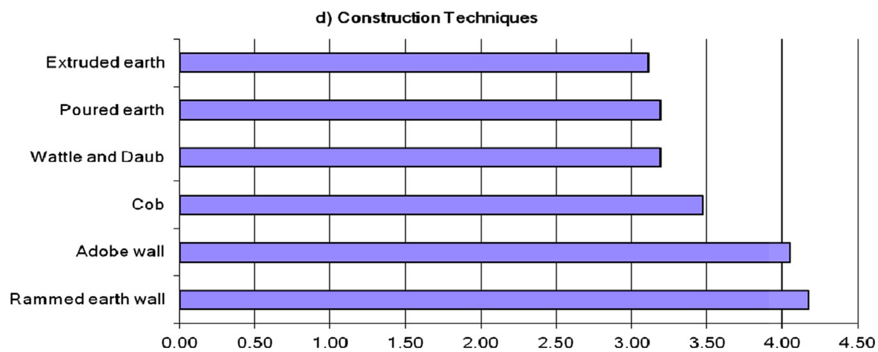

Fig. 48. Analysis of the construction techniques applied in earth architecture and earth buildings.

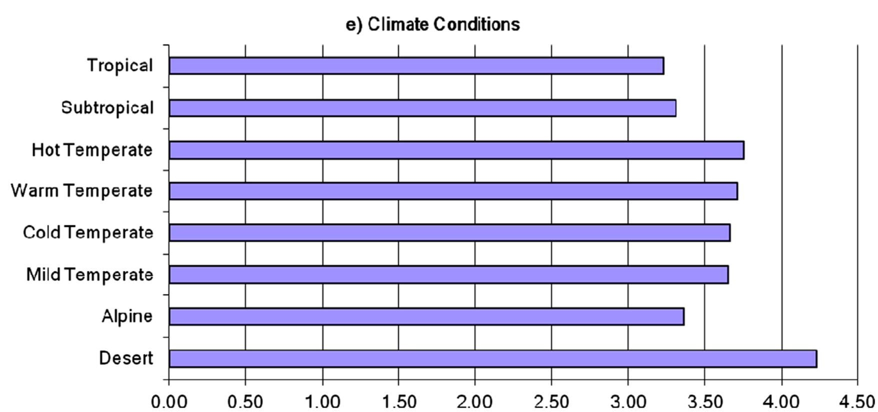

Fig. 49. Perceived suitable climate conditions analysis for earth architecture and earth buildings.

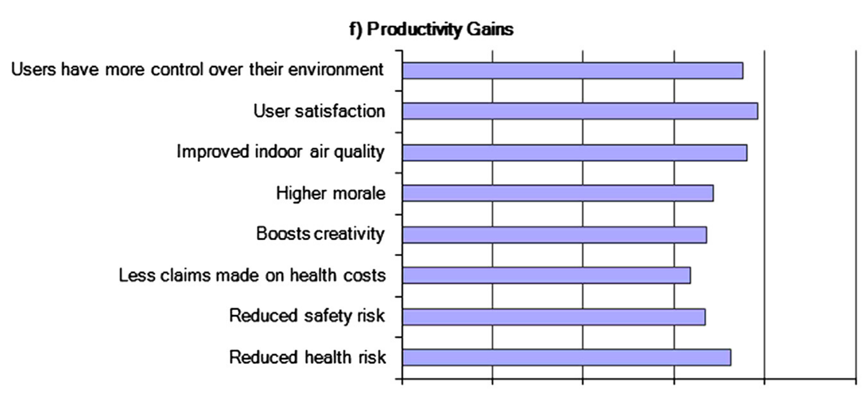

Fig. 50. Productivity gains analysis in earth architecture and earth building.

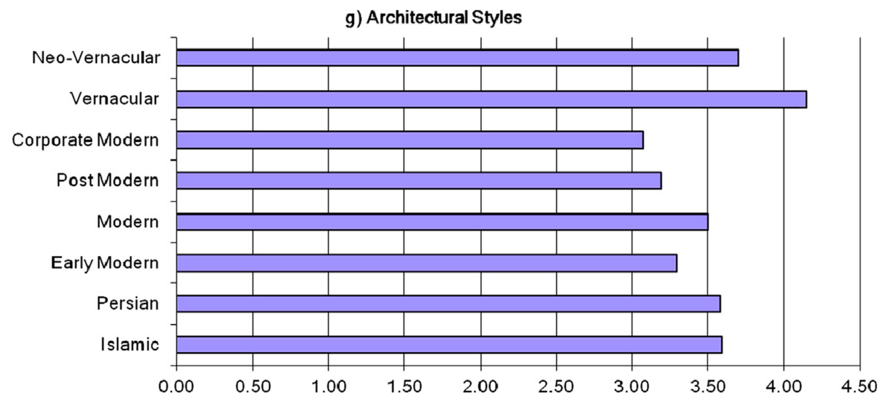

Fig. 51. Regression analysis of architectural styles in earth architecture and earth building.

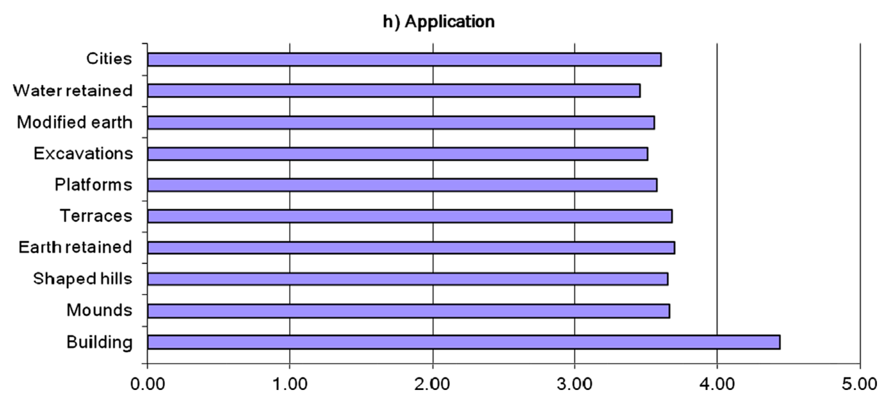

Fig. 52. Application analyses in earth architecture and earth building.

Table 11
Regression results of the six surveyed countries.

		Coefficients	*X1*	*X2*	*X3*	*X4*	*X5*	*X6*	*X7*	*X8*
1	Australia	2.31	−0.31	0.05	0.21	0.29	0.00	0.48	0.002	2.05E−07
2	India	2.13	−0.17	−1.04	0.17	0.14	0.14	0.39	0.44	0.76
3	Iran	3.02	−0.74	0.14	−0.27	−0.14	7.3E−5	0.38	0.00	0.14
4	Malaysia	−9.73	−1.04	0.24	1.28	0.19	0.00	1.9E−3	0.00	1.5E−3
5	UK	1.33	−0.04	−0.44	0.42	−0.05	0.45	8.35E−12	3.32E−20	0.10
6	USA	0.99	−0.20	−0.09	0.17	−0.02	0.00064	0.00	0.0060	0.00

Shaded values were rejected because their *P*-values are more than 0.05.

- H_1 (alternative hypothesis): $\beta_i \neq 0$.
  The independent variable, X_i, is important for predicting the dependent variable (Y).
  Whereas the analysis has five independent variables so the analysis has five null hypotheses and five alternative hypotheses.

2. *Setup confidence level*: default confidence level in MS EXCEL is 95% therefore the level of significance is 0.05 [24].
3. *Analysis of these hypotheses*: responses to questions 41–48 are independent variables and responses to question 51 are the dependent variable. These variables are inputted into MS EXCEL and MS EXCEL gives a coefficient and a *P*-value for each of these independent variables (β_I (i=0,1,2,3,4). The coefficients show the impact of these independent variables on the dependent variable and signs of these coefficients show the direction of the impacts (positive or negative). The *P*-value proves or rejects the null hypothesis. If the *P*-value of X_i is less than the level of significance (0.05), then the null hypothesis is rejected, but if the *P*-value of X_i is greater than the level of significance (0.05), then the null hypothesis is proven (Fisher, 1960). Decisions about the hypotheses for the six surveyed countries in the multiple regression analysis are shown in Table 11.

Table 11 shows the regression results of the effective parameters based on the experts' opinions in earth architecture and earth buildings in the six surveyed countries. It is evident that the *X*3 and *X*5 variables had no effective impact on earth architecture and earth buildings in Australia, i.e. "environmental" and "climate conditions" had no impact on Australia's earth architecture. Based on the regression analysis, variables *X*4, *X*7 and *X*8 had an influence on earth architecture and earth buildings and that "construction techniques", "architectural styles" and "applications" were influential on earth architecture in India. Regression analysis shows the significance of variables of *X*3, *X*4, *X*5, *X*6, and *X*8 in Iran, expressing the importance of "environmental conditions", "construction techniques", "climate conditions", "productivity gains", "architectural styles", and "overall development" in Iran's earth architecture. Based on the regression analysis in Malaysia, it is evident that the four variables, "materials", "construction techniques", "productivity gains", and "applications", are significant in

Malaysia's earth architecture. The variables $X4$–$X8$ have proven influential in the UK's earth architecture, showing the importance of "construction techniques", "climate conditions", "productivity gains", "architectural styles" and "applications" in the UK.

As an interesting result, American opinion emphasized "climate conditions" and "architectural styles" in the USA's earth architecture, identifying the high level of materials and construction techniques in the USA.

Engineers and architects can use earth materials and earth buildings as closed effective systems to improve recovery, maintenance and material costs, which are all very important considerations in building and architecture. Furthermore, different building categories use different earth materials in various projects according to the cost effectiveness in the respective country.

The importance of clay and sand as main materials in earth buildings is clear. Although these materials must be used as the main materials, other materials such as straw, lime, waste materials, and rice husk are also suitable soil stabilizers. Other soil stabilizers such as cement, flyash, nano-materials and POFA can be used in earth buildings and earth materials, but their significance is relatively low. However, more research is required on the role of nano-materials as a new soil stabilizer in earth buildings, because their performance is not clear. Engineers and architects must consider "sustainability and their elements" as main factors in the environmental control of earth architecture and earth buildings, particularly since "sustainability" has proven to be an effective factor in controlling built environments in earth buildings and earth architecture. Since "sustainability and their elements" have various standards, applying them in controlling earth buildings and earth materials in various countries is easily accomplished. Experts suggest the importance of "rammed earth walls" in earth architecture and earth buildings, which have proven to have good performance in earth buildings, although engineers and architects can use "adobe wall", "cob", "poured earth", "wattle and daub" and "extruded earth" as further selections in practice. Earth materials and earth buildings can, according to experts, be used in all climatic conditions, but are most suitable for desert conditions. However, earth buildings and earth materials can be readily used in all other climates. Earth buildings and earth materials can be used to promote "environment protection", "user satisfaction", and "reduced health risk". Engineers and architects can deploy earth architecture to coordinate it with health-enhancing practices. The naturally occurring materials are environment friendly and they increase the user's satisfaction in practice. Architects and engineers can also improve the indoor air quality by using earth materials in building. Earth buildings and earth applications can be used in various architectural styles, however, it seems that vernacular architecture and neo-vernacular architecture are the most popular since they share many characteristics of vernacular architecture in practice. Other popular styles recognized by engineers and architects include Islamic, modern and Persian architectural styles in earth buildings and their applications. Earth materials are used in various applications throughout cities, as water and earth retainers, modified earth, in excavations, platforms, terraces, to shape hills, and mounds, but the main application is in earth buildings. If engineers and architects persevere with the use of earth materials in various applications then we can attain sustainable cities in the close future. The building industry in various countries requires different conditions; consequently, the outlook on earth architecture and its future differs in various countries. Based on the experts' opinions and regression analyses, it suggests that Australia's earth architecture focuses on the development of cost savings ($X1$), materials ($X2$), construction techniques ($X4$), productivity gains ($X6$), architectural styles ($X7$), and applications ($X8$). Experts believe that the below equation captures the process of earth architecture in Australia:

$$Y = 2.31 - 0.31(X1) + 0.05(X2) + 0.29(X4) + 0.48(X6) + 0.002(X7) + 0.000000205(X8)$$

where Y is the earth architecture's level.

Earth architecture's future in India is very different: construction techniques ($X4$), architectural styles ($X7$), and applications ($X8$) as the only recognized effective factors in India, suggesting that these three factors are what Indian architects and engineers should focus on in future developments. Experts believe that the below equation captures the earth architecture process in India:

$$Y = 2.13 + 0.14(X4) + 0.44(X7) + 0.76(X8)$$

Earth architecture's future in Iran depends on environmental conditions ($X3$), construction techniques ($X4$), climate conditions ($X5$), productivity gains ($X6$), and applications ($X8$). It suggests that Iranian experts focus on the development of these five factors, which are the most effective in the future of earth architecture in Iran. Experts believe that the below equation captures the earth architecture process in India:

$$Y = 3.02 - 0.27(X3) - 0.14(X4) + 0.000073(X5) + 0.38(X6) + 0.14(X8)$$

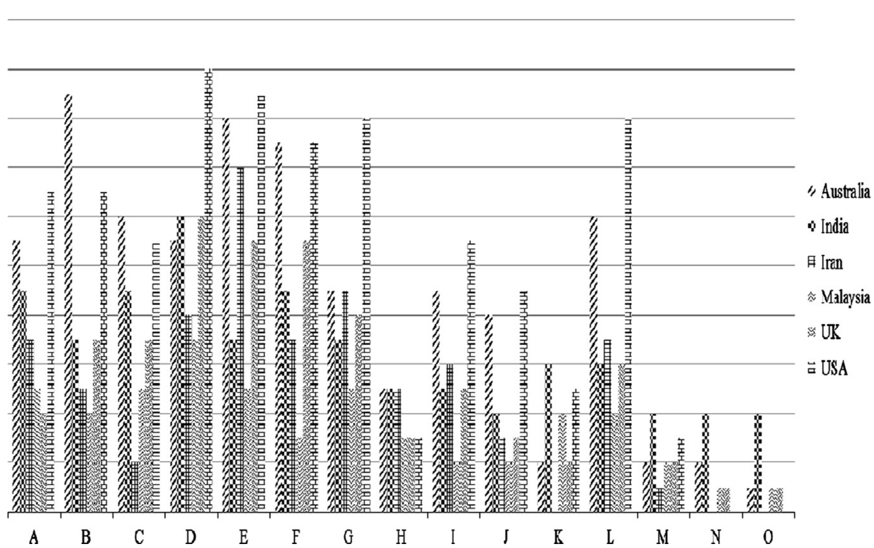

Fig. 53. Distribution of information availability of related earth architecture and earth building topics.

Table 12
Key availability of information on earth architecture and earth building.

	Topic	Option
1	Earth products	A
2	Environmental and economic cost benefit case studies	B
3	Earth building emerging trends	C
4	Earth projects	D
5	How to design earth building	E
6	Reviews and profiles of existing earth building projects	F
7	Engineering or scientific information	G
8	How to market an earth building	H
9	Earth building and earth architecture accreditation course	I
10	How to manage an earth building	J
11	Earth building players	K
12	How to maintain an earth building	L
13	Earth builder players	M
14	Business management information	N
15	Curriculum for senior executives	O

It is a fact that Malaysia can further develop earth architecture in practice. Regression shows that materials ($X2$), construction techniques ($X4$), productivity gains ($X6$), and applications ($X8$) are influential factors in earth architecture's future in Malaysia. This research suggests that Malaysian experts focus on the development of earth materials, construction techniques in earth architecture, productivity gains and various applications of earth architecture in practice. Experts believe that the below equation captures the earth architecture process in Malaysia:

$$Y = -9.73 + 0.24(X2) + 0.19(X4) + 0.0019(X6) + 0.0015(X8)$$

British experts believe that construction techniques ($X4$), climate conditions ($X5$), productivity gains ($X6$), architectural styles ($X7$), and applications ($X8$) are effective factors in earth architecture's future in the UK. It shows the high regard for construction techniques, climate conditions, productivity gains, architectural styles and applications in earth architecture's future in the UK. It suggests that British experts should further focus on the

Table 13
Guideline for the development of earth architecture and earth buildings.

Guideline for development of earth architecture and earth buildings	
Problem	**Solution**
Management of interest level and involvement level is a complex process in earth architecture and earth buildings	1. Greater effort made to increase knowledge of earth architecture and earth buildings via various training systems such as training courses, lectures, manuals, for researchers, architects and engineers 2. More attention in "earth building tools in construction" as a new parameter in the development of earth architecture 3. More attention on historical civilizations of various countries as a guide to earth architecture's future
The deficient existing national codes on earth architecture and earth buildings in various countries	4. Customize "earth building tools in construction" codes to address the specific requirements of earth buildings for each country 5. Achieve accreditation through training courses to become accredited professional experts 6. Increase the number of training courses on details of design and construction in earth buildings
The shortage of national guidelines on earth architecture and earth buildings in various countries	7. The development of national guidelines to include details on design and construction techniques to make a shift towards recognizing earth architecture and earth building as a sector of the building industry 8. Achieve accreditation through training courses to become an accredited professional 9. Raise awareness in social and environmental professions to promote vernacular buildings in earth buildings and earth architecture 10. Continued training courses and seminars
Propagating awareness about the role of the ICOMOS in earth architecture's future.	11. Establish national societies with the aid of ICOMOS in various countries 12. More support for the ICOMOS by governments, building industries, and related organizations in various countries
Identifying triggers, drivers, obstacles and reasons for earth building and earth architecture to increase their speed of development, particularly since it is very slow to progress in various countries	13. More attention must be given to the client, architects and engineers as main triggers 14. Make general and technical information about earth architecture and earth buildings more accessible to clients 15. Design an integrated process where responsibility is shared 16. Consider the pre-design stage of the building process as a main step in earth buildings 17. Consider rising energy costs and environmental conditions as main drivers in the development of earth architecture 18. Increase educational programs and awareness through various systems such as seminars, workshops, conferences, publications, TV programs and academic degrees on earth architecture 19. Emphasize "achieving lower life-cycle costs" in developing countries and "being part of an industry that values the environment" in developed countries in order to increase the interest of experts to earth architecture and earth buildings 20. Emphasize "sustainable development" of earth architecture and earth buildings 21. Introduce the clients to the advantages of earth buildings, such as low life-time cost and minimal environmental demands

Table 13 (*continued*)

Guideline for development of earth architecture and earth buildings	
Problem	**Solution**
How do we reduce the building costs in practice?	22. More attention on earth architecture and earth buildings such as maintenance cost, material cost, construction cost, and recovery cost, which are lower than other building materials in practice
What is the importance of main materials and soil stabilizers in earth building and earth materials? And which soil stabilizers are the most suitable in earth materials and earth buildings?	23. Clay and sand are the main materials used in earth buildings 24. Straw, lime, waste materials, rice husk are used as soil stabilizer, in order of importance 25. Soil stabilizers such as cement, flyash, nano-materials and POFA can be used in earth buildings and earth materials, but their significance is relatively low in earth buildings 26. Further work on the role of nano-materials as a new material in earth buildings is suggested since currently their performance in earth materials and earth buildings is not clear
How do we increase awareness on the importance of earth buildings and earth architecture in built environments?	27. More attention on the sustainability aspect of earth architecture and earth materials is necessary 28. More attention on the advantages of earth materials such as less pollution, waste minimization, and minimized site impact and their importance in built environment is necessary
Which construction techniques are better than others in earth buildings and earth architecture?	29. Consideration of rammed earth walls as the most suitable construction technique in earth architecture and earth buildings 30. Introduction of adobe walls, with a commitment to reduce their few disadvantages in the future 31. To do more research on cob, wattle and daub, poured earth, and extruded earth to further develop them as suitable construction techniques in future
Ambiguity of climate conditions and development of earth architecture and earth buildings in various countries	32. Earth materials and earth buildings can be used in all climate conditions although the role of soil stabilizers is very important in various climate conditions 33. Desert climate provides the best conditions in the development of earth architecture and earth buildings in practice
How do we increase the productivity gains in earth architecture and earth buildings?	34. More attention on user satisfaction, reduced health risk, and improved indoor air quality of earth materials and earth buildings is necessary
Which architectural style is the best and most suitable for earth building?	35. The best architectural styles are vernacular and near-vernacular architecture for earth buildings 36. Various architectural styles can be used in earth buildings but it is suggested that experts use vernacular and near-vernacular architecture for earth buildings
What are the applications of earth architecture and earth materials in practice?	37. Earth materials can be used in various applications 38. Experts can use earth architecture in cities, water retained, modified earth, excavations, platforms, terraces, earth retain, shape hills, and mounds 39. Buildings are the main application of earth architecture in practice
Ambiguity of information on effective factors and requirements in development of earth architecture and earth buildings in USA, UK, Iran, Malaysia, India, and Australia	40. Evaluation of earth architecture and their effective factors done in this research suggest that experts focus on the below factors to develop earth architecture and earth buildings in their countries 41. USA: climate conditions, and architectural styles 42. UK: construction techniques, climate conditions, productivity gains, architectural styles, and applications 43. Iran: environmental conditions, construction techniques, climate conditions, productivity gains, and applications 44. Malaysia: materials, construction techniques, productivity gains, and applications 45. India: construction techniques, architectural styles, and applications 46. Australia: cost saving, materials, construction techniques, productivity gains, architectural styles, and applications

development of these factors in order to advance the development of earth architecture in the future more than it has been in the past. According to the results, experts believe that the below equation captures the earth architecture process in the UK:

$$Y = 1.33 - 0.05(X4) + 0.45(x5) + 8.35E-12(X6) + 3.32E-20(X7) + 0.10(X8)$$

The results show that American experts believe that their country must focus on climate conditions ($X5$), and architectural styles ($X7$) only. Although the existing research shows that American experts have increased their level in quality/quantity in regard to materials and construction techniques, earth architecture's future in the USA needs to focus on climate conditions and architectural styles of earth architecture since they are the only factors that had any effect on earth

architecture in the USA. It appears that experts believe that the below equation captures the earth architecture process in the USA:

$$Y = 0.99 + 0.00064(X5) + 0.006(X7)$$

4.4.8. Section 7

4.4.8.1. Required information on Earth architecture and Earth buildings. This part evaluates the national building industry's earth architecture and earth building information requirements and their corresponding level of development related to this information.

4.4.8.2. Information requirements for Earth architecture and Earth buildings. Experts were queried: What information do you require in regard to earth building and earth architecture? The results show the significance of requirements of earth architecture and earth buildings. It shows that most experts need information and detailed requirements addressing "How to design earth buildings", "Environmental and economic cost benefit case studies", "Reviews and profiles of existing earth building projects", "Engineering or scientific information" and "How to maintain an earth building", as illustrated in Fig. 53. It is interesting to note that all items only registered a low awareness and educational training in regard to earth architecture and earth buildings in practice in all countries.

4.4.8.3. The satisfaction level. In regard to the available information, experts were then asked: What is your degree of satisfaction with the current level of information available about sustainable buildings? Most experts were not completely satisfied with the current level of earth architecture and earth building information available in their countries, opting to choose the very low level of satisfaction option for various kinds of information availability on earth architecture and earth buildings. The result shows quite a disparity between requirements and a reasonable level of satisfaction. Although various researchers have investigated earth materials and earth buildings, further assessment is required on earth buildings and earth architecture, emphasizing the necessity of further research in these six surveyed countries.Table 12.

5. Conclusion

The results analyse experts' opinions on the existing earth architecture and earth buildings by means of separating the various stages of the building process into seven stages and analyzing them separately. As a result, possible solutions, beneficial details and some necessary precautions have been identified that can assist to overcome these problems and limitations and make earth buildings a viable option for the building industry. According to the problems and deficiencies identified through the online questionnaire, solutions have been proposed, as illustrated in Table 13.

Acknowledgement

The authors would like to thank the Department of Architecture at the National University of Malaysia for their support.

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